Defence Research and Development Canada
Recherche et développement pour la défense Canada

DEFENCE DÉFENSE

Arctic Surveillance

Civilian Commercial Aerial Surveillance Options for the Arctic

Dan Brookes
DRDC Ottawa

Derek F. Scott
VP Airborne Maritime Surveillance Division
Provincial Aerospace Ltd (PAL)

Pip Rudkin
UAV Operations Manager
PAL Airborne Maritime Surveillance Division
Provincial Aerospace Ltd

Defence R&D Canada – Ottawa

Technical Report
DRDC Ottawa TR 2013-142
November 2013

Canada

Arctic Surveillance

Civilian Commercial Aerial Surveillance Options for the Arctic

Dan Brookes
DRDC Ottawa

Derek F. Scott
VP Airborne Maritime Surveillance Division
Provincial Aerospace Ltd (PAL)

Pip Rudkin
UAV Operations Manager
PAL Airborne Maritime Surveillance Division
Provincial Aerospace Ltd

Defence R&D Canada – Ottawa

Technical Report
DRDC Ottawa TR 2013-142
November 2013

Principal Author

Original signed by Dan Brookes

Dan Brookes

Defence Scienist

Approved by

Original signed by Caroline Wilcox

Caroline Wilcox

Head, Space and ISR Applications Section

Approved for release by

Original signed by Chris McMillan

Chris McMillan

Chair, Document Review Panel

This work was originally sponsored by ARP project 11HI01-Options for Northern Surveillance, and completed under the Northern Watch TDP project 15EJ01

Preface

This report grew out of a study that was originally commissioned by DRDC with Provincial Aerospace Ltd (PAL) in early 2007. With the assistance of PAL's experience and expertise, the aim was to explore the feasibility, logistics and costs of providing surveillance and reconnaissance (SR) capabilities in the Arctic using private commercial sources. Although this investigation is primarily geared toward maritime SR activities using small commercial (manned) aircraft, surveillance of land and the potential use of Unmanned Air Vehicles (UAVs) are also considered. This study does not consider the use of civilian commercial aircraft to carry out interdiction activities, since these actions and the specialized infrastructure necessary to perform them are the responsibility of police and military authorities. Where possible, the Scientific Authority (and lead author) has tried to indicate which contributions are his alone, and which contributions are attributable to the PAL authors since some of their material contains a number of expert opinions without supporting material or references.

Unless expressly stated, with supporting references, the material in this report is solely the opinions of the authors, and does not represent any official concept or doctrine of the Government of Canada or the Department of National Defence in general, or Defence R&D Canada specifically.

This page intentionally left blank.

Abstract

The heightened interest in the Arctic has prompted the Canadian Government to investigate effective and affordable methods of monitoring this vast area, including private sector airborne surveillance. This study was accomplished with domain expertise from Provincial Aerospace Limited of St. John's, NL; it describes their current worldwide surveillance, reconnaissance and enforcement activities, and extrapolating them to Canada's North. Similar arctic services would require supplementing their current fleet with manned aircraft out of Goose Bay or Iqaluit and one at Inuvik, providing surveillance of up to 4000 h/year at approximately $5000/h with 8 h missions every 1.5 to 2 days. This would allow monitoring of the arctic approaches and internal waterways on a regular basis at roughly half the cost of an Aurora. Small Remotely Piloted Vehicles (RPV) for tactical surveillance and reconnaissance were also briefly studied. New miniaturized devices allow small RPVs with limited payload capacities to carry a mixture of electro-optic and infrared sensors, Automatic Identification System receivers, miniature (short range) Synthetic Aperture Radars, etc. These platforms offer much smaller requirements for fuel, maintenance and operating crews, at a lower cost. However, they must still prove their capabilities in the harsh Arctic environment.

Résumé

L'intérêt marqué pour l'Arctique a incité le gouvernement du Canada à examiner des méthodes de surveillance efficaces et abordables, y compris les services de surveillance aérienne offerts dans le secteur privé, pour cet immense territoire. La présente étude réalisée avec l'expertise de la société Provincial Aerospace Limited, de St. John's (NL), décrit les activités mondiales actuelles de surveillance, de reconnaissance et de renforcement de l'entreprise, et les extrapole pour le nord du Canada. Pour des services semblables dans l'Arctique, il faudrait ajouter à sa flotte actuelle un aéronef piloté à Inuvik, de même qu'à Goose Bay ou Iqaluit, afin d'offrir jusqu'à 4 000 h de surveillance par an, au coût approximatif de 5 000 $ par heure, avec des missions de 8 h tous les 1,5 à 2 jours. Cela permettrait de surveiller régulièrement les approches dans l'Arctique et les voies navigables intérieures pour environ la moitié du coût d'exploitation d'un Aurora. Les petits véhicules téléguidés (VTG) pour la reconnaissance et la surveillance tactique ont également été examinés brièvement. De nouveaux appareils miniaturisés permettent aux petits VTG ayant une capacité de charge limitée de transporter des détecteurs électro optiques et infrarouges, des récepteurs du Système d'identification automatique, des radars à synthèse d'ouverture (courte portée) et autres. Ces plateformes nécessitent beaucoup moins de carburant, d'entretien et d'équipage à un moindre coût. Toutefois, il reste à démontrer leurs capacités dans les conditions difficiles de l'Arctique.

This page intentionally left blank.

Executive summary

Arctic Surveillance: Civilian Commercial Aerial Surveillance Options for the Arctic

Brookes, D.; Scott, D.F.; Rudkin, P.; DRDC Ottawa TR 2013-142; Defence R&D Canada – Ottawa; November 2013.

Introduction: With ever increasing economic development of the Canadian North, coupled with the anticipation of global climate change, shipping traffic within and through the Canadian Arctic Archipelago is expected to increase markedly in the coming decades. This may substantially raise the potential for marine disasters caused by the sinking and break-up of ships carrying toxic substances, or search and rescue (SaR) incidents involving tourist vessels. The current surveillance and reconnaissance (SR) resources available to cover such a vast area are very limited, due to the sparse population and consequent lack of infrastructure. For any one organization to take on the SR burden the cost might be prohibitive. This has prompted the Government of Canada (GOC) to explore ways of improving SR through a whole-of-government approach involving cooperation between such organizations as the Department of National Defence (DND), Transport Canada, Royal Canadian Mounted Police (RCMP), Environment Canada (EC), Fisheries and Oceans Canada (DFO), Natural Resources Canada (NRCan), etc.

An example of such cooperation that provides surveillance of maritime shipping lanes and fishing areas already exists on Canada's East and West Coasts. DFO has a multi-year contract with Provincial Aerospace Limited (PAL), a civilian aerospace company, to conduct airborne surveillance over these areas. PAL currently operates four King Air 200 aircraft specially equipped with multi-mode radar, day and night-time imaging systems, data management and communications systems etc.—two on each coast (excluding the Arctic)—providing about 7000 h of in-air service at a cost of under $2200 per hour. The information that is obtained from such flyovers is shared with DND to provide Maritime Domain Awareness (MDA) and help generate the Recognized Maritime Pictures (RMP) for both coasts. However, this company does not currently carry out such activities in the Arctic because: a) it is not part of their mandate, b) they currently lack the capacity since their fleet is fully engaged on both the East and West Coasts, and c) most of their aircraft are not suited to unpaved runways. The purpose of this report was to obtain their expert opinions regarding the resources that would be required by PAL if they were to carry out similar operations in the Arctic; to estimate the feasibility, logistics and costs to inform the GOC. This focus has been primarily on maritime enforcement and SR activities using fully manned commercial aircraft such as (but not limited to) the King Air, Dash 8 and possibly small unmanned airborne vehicles (UAV)'s.

This report describes some of the history behind PAL's current surveillance activities, both at home and abroad, giving testimony to their experience, expertise, and competence at providing such services. It also describes some of their current concepts of operation (CONOPS) for enforcement and SR supporting the GOC, and how these CONOPS could be extrapolated to the Canadian North[1]. The report also tries to highlight the importance of understanding the roles that a civilian surveillance service provider can and cannot play regarding enforcement, security and

[1] Here, and elsewhere in this report, "the North" refers to Canada's northern areas located between latitudes of 60° N and 90° N (i.e. the geographic North Pole).

defence as well as potential pitfalls associated with trading enforcement capabilities for purely SR capabilities.

This study does not consider the use of civilian commercial aircraft to carry out interdiction activities, since these actions and the specialized infrastructure necessary to perform them are the responsibility of police and military authorities. However, by engaging the private sector to provide SR, military assets will be able to concentrate operations on military issues.

Results: Based on the expert opinion of PAL, a rough estimate of the additional resources needed for them to provide civilian enforcement and SR services in the Arctic is to increase the size of their current fleet by at least two additional manned aircraft (not necessarily King Air 200s) stationed in the Arctic: one in the East at Goose Bay or Iqaluit and one in the West at Inuvik. According to their expert opinion, these aircraft could provide up to 4000 h of surveillance per year, costing about $5000 per flight hour (FH). Each aircraft would fly a mission about 8 h long every 1.5 to 2 days. This would probably allow the aircraft to monitor most, if not all, of the approaches to the Arctic Archipelago, as well as its internal waterways, on a more regular basis than by current sovereignty exercises. Although it wouldn't provide the same enforcement capability as a CP-140 (a.k.a. Aurora) maritime patrol aircraft (MPA)—since it is not equipped with magnetic anomaly detectors, sonobuoys or any weapons—it could provide a more persistent presence, at a fraction of the cost of an Aurora at up to $25k per FH. Two new permanent bases would likely require additional infrastructure (hangars etc.). It may be more cost-effective for the GOC to provide, as Government Furnished Equipment, some of, or all of, the infrastructure and equipment (aircraft maintenance, sensors and associated systems etc.) necessary to the mission. These assets could then be managed by the contractor.

If surveillance and reconnaissance are the only considerations, and not an overt expression of presence, then with the appropriate concepts of operation, a small Remotely Piloted Vehicle (RPV/UAV) might suffice. Such platforms as the Aerosonde, ScanEagle, Integrator or similar sized systems, with smaller, less capable electro-optic and infrared (EO/IR) sensors, short range miniature Synthetic Aperture Radar systems (e.g. NanoSAR), Automatic Identification System receivers, etc, might meet the basic requirements, assuming they can operate effectively in such extreme environments. Although less capable than a fully manned and equipped aircraft, these platforms require a much smaller footprint in terms of fuel requirements, as well as maintenance and operating crews, with a consequential reduction in cost. However, despite the impressive number of successful mission hours logged by such systems as the ScanEagle in the Middle East during Iraqi and Afghanistan conflicts, they (and their sensors) must still prove themselves in the harsh Arctic if winter use is required.

Significance: Civilian industry in Canada has the capability to provide the GOC with a cost, and operationally, effective maritime surveillance program for the Canadian Arctic.

Future plans: It would be extremely useful to evaluate concepts of operation for small UAVs, with the size and sensor payloads mentioned earlier. These would be based on a combination of simulation and in-situ experiments in the harsh Arctic environment. Without such trials informed decisions are not possible. Subsequent to this, it would also be extremely useful to perform a more detailed, full cost-benefit analysis to compare the performance of civilian MPA (variants of the King Air, Dash 7/8, etc) as well as both large and small UAVs to the current CP-140 Aurora.

Sommaire

Arctic Surveillance: Civilian Commercial Aerial Surveillance Options for the Arctic

Brookes, D.; Scott, D.F.; Rudkin, P.; DRDC Ottawa TR 2013-142; R & D pour la défense Canada – Ottawa; novembre 2013.

Introduction ou contexte: La croissance constante du développement économique dans le Nord canadien et les changements climatiques mondiaux prévus devraient accroître de façon importante la circulation maritime dans les eaux de l'archipel arctique canadien au cours des prochaines décennies. Cela pourrait augmenter considérablement les risques de catastrophe maritime causée par le naufrage de navires transportant des matières dangereuses ou d'incidents de recherche et sauvetage (SAR) liés aux navires d'excursions. Les ressources de surveillance et de reconnaissance actuellement disponibles pour couvrir un tel territoire sont très restreintes étant donné la population clairsemée et, par conséquent, le manque d'infrastructures. Les coûts associés à la surveillance et la reconnaissance peuvent s'avérer inabordables pour une seule organisation. Cela a donc incité le gouvernement du Canada (GC) à examiner des moyens d'améliorer la situation par l'entremise d'une approche pangouvernementale à laquelle collaborent des organisations telles que le ministère de la Défense nationale (MDN), Transport Canada, la Gendarmerie royale du Canada (GRC), Environnement Canada (EC), Pêches et Océans Canada (MPO) et Ressources naturelles Canada (RNCan).

Une collaboration assurant la surveillance des voies de navigation maritime et des zones de pêche existe déjà sur les côtes est et ouest du Canada. Le MPO a conclu un contrat pluriannuel avec la société Provincial Aerospace Limited (PAL), une entreprise aérospatiale civile, pour effectuer de la surveillance aérienne au-dessus de ces zones. PAL exploite actuellement quatre avions King Air 200 (deux sur chaque côte, à l'exception de l'Arctique) équipés de radars multimodes, de systèmes d'imagerie diurnes et nocturnes, de systèmes de communication et de gestion des données et autres. Ils effectuent environ 7 000 h de services aériens, au coût de 2 200 $ l'heure. Les données recueillies durant les vols sont transmises au MDN afin de le tenir informé de la situation maritime sur les deux côtes. Toutefois, l'entreprise n'effectue actuellement pas ce genre d'activités dans l'Arctique pour les raisons suivantes : a) cela ne fait pas partie de son mandat; b) elle ne dispose pas des ressources nécessaires puisque sa flotte est entièrement mobilisée sur les côtes est et ouest; c) la plupart de ses avions ne sont pas adaptés aux pistes sans revêtement. Le présent rapport visait à obtenir l'avis des experts de PAL concernant les ressources dont elle aurait besoin pour effectuer le même type d'opération dans l'Arctique, en plus d'évaluer la faisabilité, la logistique et les coûts à titre informatif pour le GC. L'accent a été mis principalement sur les activités de surveillance, de reconnaissance et d'application de la loi dans les zones maritimes à l'aide d'avions commerciaux avec effectif complet tels que (mais sans s'y limiter) le King Air, le Dash 8 et possiblement de petits véhicules téléguidés (VTG).

Le présent rapport relate une partie de l'historique des activités actuelles de surveillance menées par l'entreprise au pays et à l'étranger, témoignage de son expérience, de l'expertise et de ses compétences à assurer de tels services. Il décrit également certains de ses concepts d'opération (CONOPS) concernant la surveillance, la reconnaissance et l'application de la loi en appui au

GC, de même que la façon dont ces CONOPS pourraient être extrapolés dans le Nord canadien[2]. Le rapport souligne l'importance de comprendre les rôles qu'un fournisseur civil de services aériens peut et ne peut pas jouer concernant l'application de la loi, la sécurité et la défense, de même que les obstacles possibles liés au remplacement de capacités d'application de la loi par des capacités de surveillance et de reconnaissance uniquement.

La présente étude ne tient pas compte de l'utilisation d'avions commerciaux pour effectuer des activités de répression puisque celles-ci et les infrastructures nécessaires relèvent des autorités policières et militaires. Toutefois, la mobilisation du secteur privé pour la surveillance et la reconnaissance permettrait d'affecter les ressources militaires à des questions militaires.

Résultats: Selon les experts de PAL, la flotte actuelle de l'entreprise devrait compter deux avions avec pilote (pas nécessairement des King Air 200) de plus pour assurer les services d'application de la loi, de surveillance et de reconnaissance dans l'Arctique : un basé dans l'est, à Goose Bay ou Iqaluit, et l'autre dans l'ouest, à Inuvik. Ces avions permettraient d'assurer jusqu'à 4 000 h de surveillance par an, au coût de 5 000 $ par heure de vol. Chaque aéronef effectuerait des missions de vol de 8 h tous les 1,5 à 2 jours. Il serait ainsi possible de surveiller la plupart, sinon la totalité, des approches de l'archipel arctique et les voies navigables intérieures de façon plus régulière que le permettent les exercices actuels de souveraineté. Il est certain que cette option n'offre pas la même capacité d'application de la loi que l'avion de patrouille maritime CP140 Aurora, puisque ces aéronefs ne sont pas équipés de détecteurs d'anomalie magnétique, de bouées acoustiques ou d'armes. Toutefois, cela assurerait une plus grande présence à une fraction du prix d'exploitation d'un Aurora qui est de 25 000 $ par heure de vol. Deux nouvelles bases permanentes nécessiteraient probablement de l'infrastructure supplémentaire (p. ex., hangars). Il serait peut être plus rentable pour le GC de fournir une partie ou la totalité de l'équipement et de l'infrastructure (p. ex., entretien des avions, capteurs et systèmes connexes) requis pour la mission. Ces biens pourraient être gérés par l'entrepreneur.

Si seules la surveillance et la reconnaissance sont prises en considération, en laissant de côté une présence ouverte, un petit véhicule téléguidé (VTG) pourrait suffire avec les concepts d'opération appropriés. Des plateformes telles que l'Aerosonde, le ScanEagle, l'intégrateur ou des systèmes de taille semblable avec des détecteurs électro-optiques et infrarouges plus petits et de capacité moindre, des systèmes radars à synthèse d'ouverture miniature et de courte portée (p. ex., NanoSAR) et des récepteurs du Système d'identification automatique pourraient répondre aux exigences de base s'ils peuvent fonctionner efficacement dans les conditions extrêmes du Nord. Malgré une capacité réduite, l'empreinte de ces plateformes en matière de carburant, d'entretien et d'équipage est considérablement inférieure à celle des avions entièrement dotés et équipés, et ce, à un coût corrélatif moindre. Cependant, en dépit des nombreuses heures de mission réussies consignées par les systèmes tels que le ScanEagle (et les détecteurs), il reste à démontrer leurs capacités dans les conditions difficiles de l'Arctique pour leur utilisation en hiver au besoin.

Importance: L'industrie civile du Canada peut offrir au GC un programme de surveillance maritime rentable et efficace sur le plan opérationnel pour l'Arctique canadien.

Perspectives: Il serait très utile d'évaluer des concepts d'opérations pour les petits véhicules téléguidés (VTG) (taille et capacité de charge limitée des détecteurs susmentionnées), s'appuyant

[2] Ici et ailleurs dans le texte, le « Nord » signifie les régions nordiques du Canada situées entre les 60e et 90e parallèles nord (p. ex., le pôle Nord géographique).

sur une combinaison de simulations et d'expériences in situ dans le rigoureux environnement de l'Arctique. Des décisions informées ne peuvent être prises sans les résultats de tels essais. Par la suite, il pourrait également être avantageux d'effectuer une analyse exhaustive des coûts et des avantages, et de comparer le rendement des avions civils de patrouille maritime (modèles du King Air, Dash 7/8 et autres), des petits et gros VTG et du CP140 Aurora actuel.

This page intentionally left blank.

Table of contents

List of figures

List of tables

This page intentionally left blank.

Acknowledgements

One of the authors (D. Brookes) would like to thank Dr. W. Chamma for some of the information that he provided related to small tactical UAVs, specifically the ScanEagle. He would also like to thank Dr. C. Helleur for his suggestions to improve the report and Mr Matthew Macleod for his early review of the original contractor's report.

.

This page intentionally left blank.

1 Introduction

With ever increasing economic development of the Canadian North, coupled with the anticipated global climate change, shipping traffic within and through the Canadian Arctic Archipelago is expected to increase markedly in the coming decades. This may substantially raise the potential for marine disasters caused by the sinking and break-up of ships carrying toxic substances, or search and rescue (SaR) incidents involving tourist vessels, downed aircraft, etc. The current surveillance and reconnaissance (SR) resources available to cover such a vast area are very limited, due to the sparse population and consequent lack of infrastructure. This has prompted the Government of Canada (GOC) to explore ways of improving SR through a whole-of-government approach involving cooperation between such organizations as the Department of National Defence (DND), Transport Canada (TC), Royal Canadian Mounted Police (RCMP), Environment Canada (EC), Fisheries and Oceans Canada (DFO), Natural Resources Canada (NRCan) etc.

An example of such cooperation, that provides surveillance of maritime shipping lanes and fishing areas, already exists on Canada's East and West Coasts: DFO has a multi-year contract with Provincial Aerospace Limited (PAL), a civilian aerospace company, to conduct airborne surveillance over these areas. PAL currently operates four King Air 200 aircraft—specially equipped with multi-mode radar, day and night-time imaging systems, data management and communications systems—that provide about 7000 h of in-air service at a cost of under $2200 per hour. The information that is obtained from such flyovers is shared with DND to provide Maritime Domain Awareness (MDA) and help generate the Recognized Maritime Pictures (RMP) for both coasts. However, this company does not currently carry out such activities in the Arctic because it is not part of their mandate. To take on this mandate they would need to increase their capacity since their fleet is fully engaged on both the East and West Coasts, and most of their aircraft are not suited to unpaved runways.

The purpose of this study is, with the assistance of PAL's expertise, to explore the feasibility, logistics and costs of providing surveillance and reconnaissance (SR) capabilities in the Arctic using private commercial sources. Although this investigation is primarily geared toward maritime SR activities using small commercial aircraft such as (but not limited to) the King Air, or Dash 7/8, surveillance of land and the potential use of Unmanned Air Vehicles (UAVs) are also considered. This study does not consider the use of civilian commercial aircraft to carry out interdiction activities, since these actions and the specialized infrastructure necessary to perform them are the responsibility of police and military authorities.

In order to define the scope of the investigation, this report begins in Section 2 by listing some of the current ISR resources available in Canada, including military, paramilitary, GOC, or private commercial capabilities. This provides a partial baseline with which to compare present and future capabilities, and to help identify those capabilities that might be extrapolated for use in the Arctic. Additional background material on PAL and its maritime surveillance operations, both domestic and worldwide, is provided in ANNEX A. Section 2 then proceeds to outline a number of questions, and additional considerations which, when addressed, may provide a minimum guide as to how those capabilities could be transitioned to the new environment. One of the key additional considerations concerns rules and regulations governing when, and where, different classes of ships are allowed into the channels and approaches of the High Arctic. ANNEX B provides a map showing how the Arctic seaways are categorized based on ice conditions, as well as a table showing when (based on historical averages) different classes of ships are allowed to safely navigate any of those regions.

Section 3 provides answers to the questions posed in Section 2, while Section 4 addresses the additional considerations listed in Section 2. Section 5 raises some important additional considerations that were identified by PAL, but not mentioned in the original SOW or reiterated in Section 2.

One of the biggest constraints on Arctic ISR is the availability of beyond-line-of-sight (BLOS) communications to convey information back to either an Arctic or Southern Operations Centre in real-time or near-real-time. Because of the Arctic's sparse population, the only infrastructure that currently provides such a link is satellite communications. The information contained in annexes C to F is supporting material, obtained from the internet, to show what capability exists, where it exists, and how much it might cost. These annexes do not cover any potential future satellite communications infrastructure. This includes the Polar Communications and Weather Satellite (PCW) constellation currently being proposed by the Canadian Space Agency, along with other government partners such as DND, and Environment Canada.

Since the subject of UAV capability is such a wide ranging topic, and an in depth treatment is beyond the scope of this report, Section 6 provides a limited overview of UAV capabilities based on unclassified and open source material. This includes the results of a limited number of available Operations Research (OR) studies that have investigated UAV utility in general and more specifically how well they compare with the CP-140 Aurora, the Canadian Forces (CF) main maritime patrol aircraft (MPA). This section also explores the potential use of small UAVs similar in size to the Aerosonde or ScanEagle as tactical assets to support other airborne or land based surveillance resources. This study is performed with due regard to the recent advances in miniaturization of electronic devices such as computer processors, advanced camera systems, synthetic aperture radar, and better communications capability. Additional supporting information on these platforms and technologies is also provided in the annexes that were not devoted to satellite communications.

2 Scope of Study

The scope of this study is based on a Statement of Work (SOW) that was intended to guide a study to be performed under a sole-sourced contract by PAL. The Scientific Authority for that contract is also the principal author of this report. The following paragraphs, and Table 1, are excerpts from that SOW, so the information on the various programs is based on what was available at the time. For example, only RADARSAT-1 imagery was available to the Integrated Satellite Tracking of Oil Polluters (ISTOP) program until RADARSAT-2 was launched and brought on-line. RADARSAT-2 wasn't even launched until December of 2007, several months after the SOW was written. Although the questions that are posed in the SOW may appear similar to those that would normally be asked by scientists working at the Centre for Operations Research and Analysis (CORA) these were developed by the Scientific Authority. The reason for this was due to the difficulty in getting CORA participation at that particular time when they had more pressing, pre-existing commitments.

Defence R&D Canada was tasked with investigating possible ways of improving Arctic Surveillance in support of Canadian Arctic Sovereignty and Security. One expected capability gap where Science and Technology (S&T) may contribute is in the area of Intelligence Surveillance and Reconnaissance (ISR), with emphasis on the surveillance aspects.

In addition to the Canadian Forces, several other government departments (OGDs) with support from private companies are currently involved in providing ISR capability throughout Canada, including the Arctic. Some of the current Canadian programs with a significant ISR content and assets include those provided in Table 1.

Table 1: A partial baseline of civilian and military Maritime ISR capabilities in Canada

Program	Gov. Dept.	Purpose	ISR Assets
National Aerial Surveillance Program (NASP)	Transport Canada	Enforce the Pollution Prevention Regulations of the Canada Shipping Act and other related legislation. When pollution is detected, charges may be laid under the Canada Shipping Act	**Dash 8**-Moncton NB. MSS 6000 surveillance system: - SLAR, - UV/IR lines scanner - EO/IR camera - High Res. Digital camera - Airborne AIS transponder **RADARSAT-1** imagery **PAL flights**-King Air 200 Sensor Suite: Radar: Litton APS-504(V)5 or IAI ELTA EL/M2022A(V)3 FLIR: FLIR Syst. Star Safire II, IR, Color CCD, Spotting Scope Camera: Nikon D2x 12.1MP Digital SLR Night-time ID: Tricor Night Illumination System Connected to Digital Nikon D2x SATCOM: MSAT, Iridium AIS: Integrated with onboard DMS

Program	Gov. Dept.	Purpose	ISR Assets
			Visual observation: up to 6 crew
1 Canadian Ranger Patrol Group	Canadian Forces, Joint Task Force North (JTFN)	Arctic Sovereignty and Security Patrols	**Visual Surveillance** with optical aids (e.g. binoculars)
National Search and Rescue Program	DFO/CCG	Search and Rescue	**DND -** Joint Rescue Coord. Centres - primary air SaR services for both air and maritime incidents - co-ordinates the activities of the Civil Air Search and Rescue Association (CASARA), **COSPAS/SARSAT**- an international SaR satellite system used to detect and locate signals from distress beacons. **Vessels(incl. hovercraft) –** with associated sensor suites **Aircraft** – 27 helicopters including BO-105, Bell 212, Sikorsky S61-N, Bell 206L,
DFO Air Surveillance Program	DFO/CCG	Multi-mission surveillance, Oceans data collection, Maritime Domain Awareness, Domestic maritime law enforcement Enforcement presence.	**PAL flights-**for sensors, see above in NASP
Canadian Ice Service	Environment Canada	Ice and iceberg monitoring	**Satellite based Sensors** -RADARSAT 1-synthetic aperture radar -Envisat – synthetic aperture radar -MODIS-multi-spectral imagery from Terra and Aqua satellites. -NOAA-AVHRR data (Advanced Very High Resolution Radiometer) **Reconnaissance aircraft**- for ice and iceberg data collection; analyses and prediction of ice & iceberg conditions, tracking.
ISTOP	Transport Canada	Integrated Satellite Tracking of Polluters	**RADARSAT-1 ScanSAR** imagery **NASP aircraft**
Project Polar Epsilon	DND-Director Joint Capability Production	Joint Space-Based wide area surveillance and support capability that will provide all-weather, day/night observation of Canada's Arctic region and its ocean approaches. The project will develop capabilities for ship detection, environ. sensing, ocean intelligence, and satellite data reception and processing.	**RADARSAT-1 ScanSAR** imagery **AIS**

SOW Requirements:

The study will be carried out with the intention of providing answers to the following questions:

1) Where would the most effective areas be, for the ISR flights to occur in the Arctic, given the current landing sites and available infrastructure? For example how much of the Labrador Sea approach to Arctic waters (Northern Labrador to Southern tip of Greenland) could be covered by air assets,
2) Are there any constraints on the time of the year regarding flying conditions or other similar considerations?
3) What additions to the current PAL fleet might be required, if any?
4) Would new bases of operation need to be established in the North, if so, what would the logistics considerations and costs estimates be (e.g. cost of new buildings, costs of fuel, skilled and unskilled manpower etc.)?
5) Are there currently any agreements with Greenland/Denmark that would allow us to fly surveillance over their waters, and possibly exchange information;
6) What would be some of the considerations, costs etc. for setting up a similar capability for the western approaches to Arctic Canadian waters such as the Beaufort Sea and Amundsen Gulf?

The following considerations should be taken into account when answering the above questions:

- Number of required surveillance hours per base (this may depend on the target types, sea vs. land);
- Mission endurance (what can be accomplished given the available air assets);
- Enforcement presence frequency by area;
- Mission equipment suite (depends on the air asset, e.g. King Air, Dash 7/8, UAV);
- Mission profiles and coordination (lead agency – DFO, DND, etc.); potential for splitting costs among participants for multi-role missions;
- Primary targets of interest (commercial vessels, fishing, ground based targets, etc.);
- Suitability of alternates;
- Main bases augmented by occasional forward operating bases (overnights); i.e. would full-time presence in the Arctic be necessary, or could the necessary presence and surveillance be accomplished with occasional flights from a southern base (similar to CF Maritime Patrol Aircraft patrols);
- Impact of ice flows on mission profiles;
- Availability of 24/7 services such as fuel;
- Hangarage (availability of airport infrastructure)
- Runway conditions;
- Communications constraints (possible difficulties associated with transmitting relevant data to southern Operations Centres in a timely fashion);
- Community, ability to attract crews and retain them;
- Local Native considerations (local employment, treaties/agreements etc.).

The above conditions are meant as a minimum guideline only, any additional considerations and information that may be pertinent to the study would also be beneficial (for example, how might private commercial flights in the Arctic be integrated with other surveillance activities such as those mentioned in the previous table).. The priority on tasks, in order of decreasing importance is as follows:

1) Maritime ISR
    a. Using manned aircraft;
    b. Using UAVs.
2) Land ISR
    a. Using manned aircraft
    b. Using UAVs.

3 Study Questions

3.1 Effective Areas

Where would the most effective areas be, for the ISR flights to occur in the Arctic, given the current landing sites and available infrastructure? For example how much of the Labrador Sea approach to Arctic waters (Northern Labrador to Southern tip of Greenland) could be covered by air assets?

The most effective areas for the ISR flights to occur in the Arctic would be at, or near, "choke" points or critical approach areas. Figure 2 illustrates potential traffic flow through the Arctic Region, and identifies the east and west approaches along with most of the major chokepoints. However, the route that is still the most popular, most used (i.e. most ice-free) way to make a complete transit through the Arctic Archipelago, going from East to West, is from Davis Strait, through Lancaster Sound, down Peel Sound then out past Cambridge Bay to Amundsen Gulf and the Beaufort Sea. In general, most recognized vessel traffic in the High Arctic does not make a full transit. Most traffic heading west from Davis Strait through Lancaster Sound only travels as far as Resolute Bay on Cornwallis Island before returning in the direction it came. Similarly, traffic entering the Arctic Archipelago from the West usually doesn't go much farther than Gjoa Haven before returning toward the Beaufort Sea.

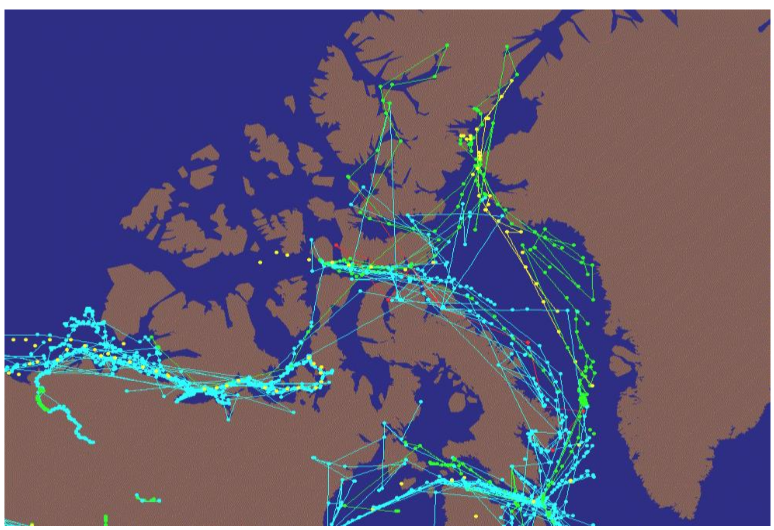


Figure 1: This illustration shows a map of the Arctic Archipelago with typical merchant vessel traffic based on the unclassified RMP for 1-July to 31-Oct. 2003 [image from an unclassified briefing by Lt(N) Jay Warwick on Merchant Shipping in the Arctic].

Given the reality that ice will remain a hurdle for vessel presence in the higher regions of the Arctic, the critical approaches to consider would be along the coastline of Labrador and along the northern approaches of the Northwest Territories (NWT) close to Inuvik. Shipping activity will focus their voyages through these areas and it would therefore be logical to conclude that the majority of the surveillance should occur in this area for early detection purposes. More tightly focused surveillance could be maintained at the choke points.

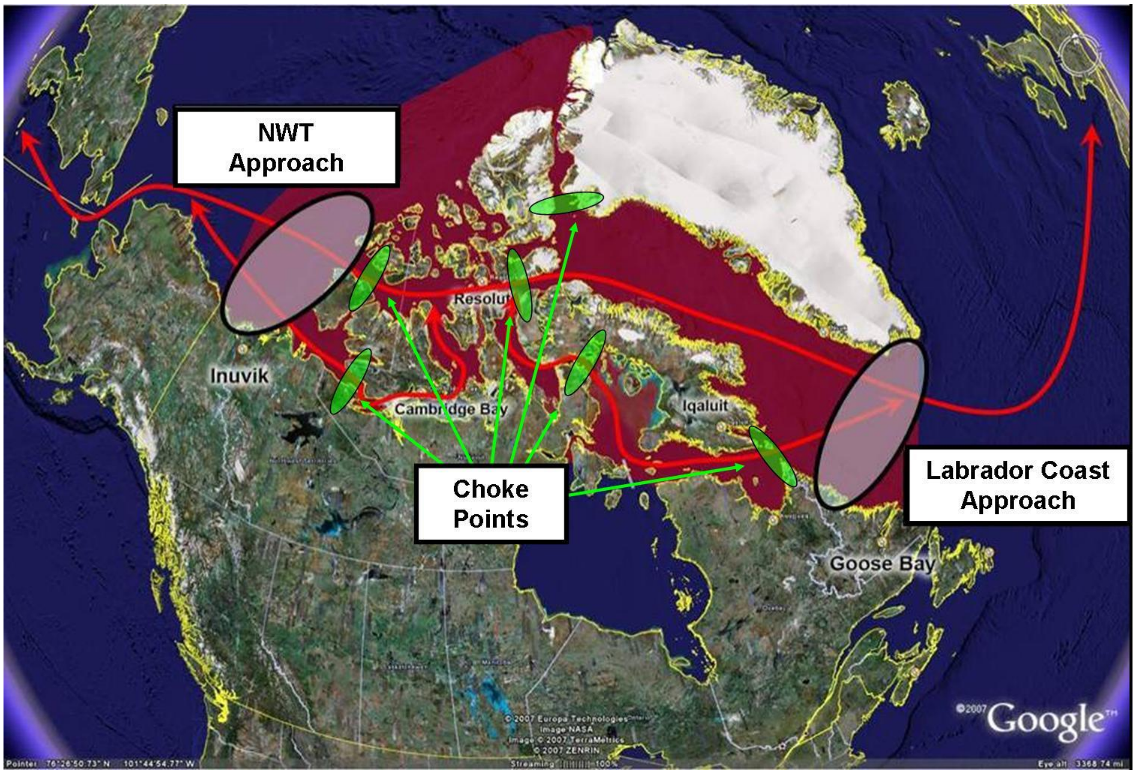


Figure 2: Reduction of future arctic ice could decrease shipping distances by up to 4,000 nmi or 7,408 km. This will introduce a significant increase in commercial traffic in Canada's North. The red-shaded area represents the potential full area of interest, the green ellipses represent the most relevant choke-points, and the thick red arrows indicate the most likely shipping routes, should the passages open up due to melting ice. .

Once a level of intelligence is acquired regarding the intensity of shipping and other activity in the North, then a holistic approach can be used to develop a concept of operations (CONOPS) for how various current and future ISR assets will be employed. For example, if the recently announced Arctic Offshore Patrol Ships (AOPS) become a reality, they could be assigned to monitor specific areas while being provided with occasional air support as required. Then other surveillance assets could focus on other areas where they are most needed.

Air assets are fully capable of providing coverage of the entire Canadian Northern territory; however, the revisit rate for any given area will depend on the size of the area, its distance from the main base of operations, and the number of available air platforms. Flight endurance, sensor capability and data communications are critical components to ensure that the surveillance aircraft can reach the tasked areas, detect, classify, identify and where necessary create enforcement presence, and then to be able to communicate the information to other surveillance assets such as patrol ships.

Given the proximity of Goose Bay to the Labrador Coast Approach shown in Figure 2 it is a logical choice to host a main base for flight operations on Canada's east coast. This is supported by a number of factors including but not limited to the following list:

- Facilities – There is an abundance of facilities in Goose Bay that are suitable for the establishment of a surveillance base of operations.
- Geographic location – The site is located next to one east coast choke point at Hudson Strait, and the critical eastern approach to the Arctic. Vessels transiting from the Atlantic must pass between the coast of Labrador and Greenland in order to gain passage through Canada's North.
- Additional area support – The area is also strategically located such that it would be cost-effective for the aircraft to provide operational support into the Newfoundland offshore areas and into the Gulf of St. Lawrence
- Human resources – The community of Goose Bay is a comparatively attractive location to draw and retain a skilled workforce of pilots, sensor operators and maintenance engineers.
- Transportation Network – The Goose Bay area is heavily serviced by aircraft with major and regional carriers such as Air Canada and Provincial Airlines. Transportation infrastructure is a critical consideration when providing spares and technical support to surveillance operations.

Iqaluit may also be a good candidate as a base of operations for Arctic airborne surveillance (Figure 4). While not as conveniently located as Goose Bay for surveillance off the East Coast, Iqaluit is the considered to be the "gateway of the Eastern Arctic" so it is better situated for High Arctic surveillance. Some of the advantages of locating there are provided in the following list:

- Facilities – There are an abundance of facilities in Iqaluit that may be suitable for the establishment of a surveillance base of operations either now or in the near future. If current facilities are insufficient, the recent rapid growth of this community could be used to spur the necessary construction of new facilities.
- Geographic location – The site is located next to the east coast choke point or critical approach to Canada. Vessels transiting from the Atlantic must pass between the coast of Labrador and Greenland in order to gain passage through Canada's north.
- Human resources – Iqaluit is a relatively large (and fast growing) community of 7500, and is the home of the Government of Nunavut as well as the home of the Nunavut Arctic College which includes the Nunavut Research Institute. It is the gateway point and supply centre for diamond and gold mines in Nunavut. The local infrastructure coupled with economic development potential for this city would make it an attractive location to draw and retain a skilled workforce of pilots, sensor operators and maintenance engineers.
- Transportation Network – The Iqaluit International Airport area is heavily serviced by aircraft with major and regional carriers such as Air Canada, First Air, and Canadian North. The airport is a paved facility capable of handling large jets and is used as a cold testing site for the Airbus 380, Boeing 777, and Eurocopter. Transportation infrastructure is a critical consideration when providing spares and technical support to surveillance operations.

On Canada's western arctic approach, there are few logical choices for the positioning of a permanent base of surveillance operations. However, the community of Inuvik (Figure 5) presents significant advantages over other potential choices in the area, including, but not limited to the following list:

- Geographic location – Inuvik is adjacent to Canada's western critical Arctic approach and is therefore logical to assume that launching missions from this base would result in more cost-effective missions than if basing the operation from somewhere else.
- Human resources – The community of Inuvik would be more attractive to attract a skilled workforce than compared to some of the other smaller areas communities.
- Transportation Infrastructure – Inuvik is serviced regularly by several air carriers on a daily basis which is critical to the support of surveillance operations in the Arctic.

Figure 3: Goose Bay is a potential main base of operation because of its strategic location next to the Labrador coast choke point and readily available facilities. The concentric circles represent 250 nmi increments, or 463 km so the outer ring represents the maximum distance that a King Air 200 could cover in one direction.

Figure 4: Iqaluit is another potential candidate for a permanent base of air surveillance operations. The concentric circles represent 250 nmi increments, or 463 km so the outer ring represents the maximum distance that a King Air 200 could cover in one direction.

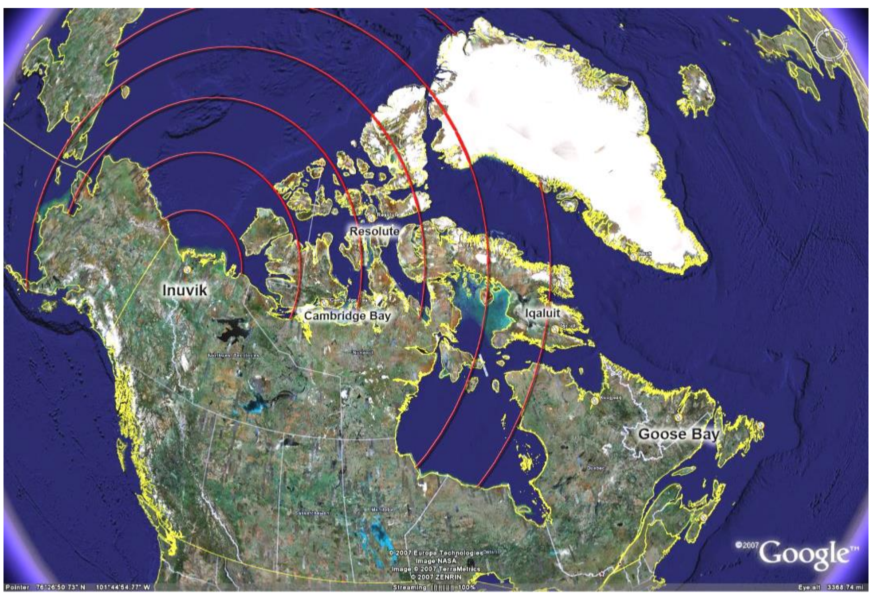


Figure 5: Inuvik has the strategic advantage of being adjacent to Canada's western critical approach into the Arctic. The concentric circles represent 250 nmi increments, or 463 km so the outer ring represents the maximum distance that a King Air 200 could cover in one direction.

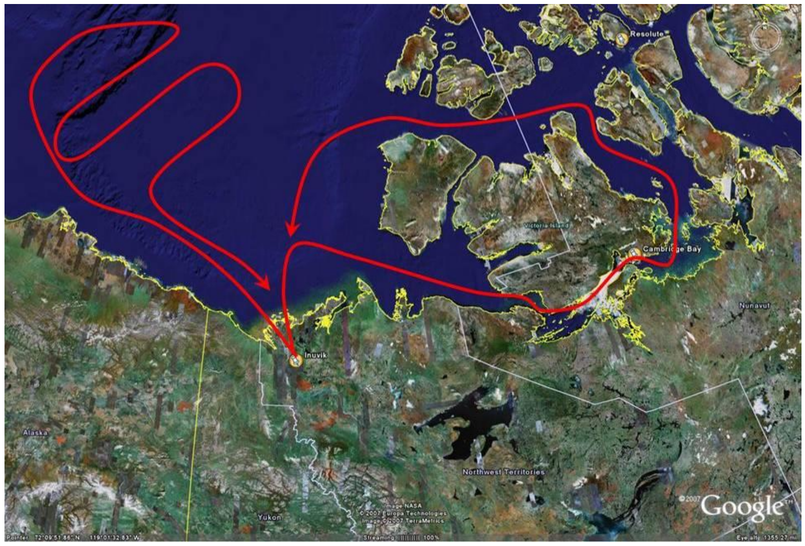


Figure 6: Missions from Inuvik can provide tactical support to patrol ships, create enforcement presence, and execute early detection in the critical western approach to Canada's North. Thick red arrows indicate notional surveillance routes and reconnaissance patterns for PAL aircraft.

3.2 Time of Year Constraints

Are there any constraints on the time of the year regarding flying conditions or other similar considerations?

Overall, there would be no constraints on the time of the year regarding flying conditions or other similar considerations. With respect to the aircraft, Canada's general aviation industry regularly flies into the North on a daily basis throughout the entire year (e.g. First Air flights to Resolute, Air Canada flights to Iqaluit). With respect to mission equipment, its performance is not impacted by the general presence or lack of poor weather conditions. Other factors, such as pack-ice or sea roughness, may impact target detection performance, but otherwise these will not impact on the ability of the aircraft to execute missions any time of the day or any time of the year.

Figure 7: Actual photo from a PAL surveillance aircraft under contract with the GOC. Canada's private sector regularly and successfully performs missions in the harsh North Atlantic. . [Photo courtesy of Provincial Aerospace Ltd.]

Some weather conditions may preclude missions from departing airports, or entering specific tasked areas. However, these conditions would be experienced and managed on a daily basis, and not on a longer term basis that would impact on the ability of the aircraft to create enforcement presence. Figure 7 shows a typical example of some of the harsh weather that PAL has flown in.

Therefore, the contractor looking to establish operations in the North should have some knowledge of these types of operations and be aware of the operating challenges and general best-practices for cold weather operations. Mission scheduling in the winter should be sensitive to long range weather forecasts, as adverse conditions could easily result in having aircraft stuck at remote bases of operations for days with no operations being conducted due to weather constraints.

Special considerations would have to be given by the operator for "cold soaking"[3] of mission equipment. Forward operating missions would definitely need to ensure that hangarage is available. Otherwise, the extreme cold soaking of mission equipment could impact on the ability of the equipment to be engaged. For example, equipment such as the radar with a rotating antenna would be severely impacted if the aircraft was cold soaked for an extended period of time. Aircraft that make use of an aircraft power unit (APU) such as the Dash-8 would have an advantage for this type of operation because it would be able to keep the cabin environment at a reasonable temperature during the period in which the aircraft is being prepared for departure.

3.3 PAL Fleet

What additions to the current PAL fleet might be required, if any?

The current Provincial Aerospace fleet of aircraft under the DFO Air Surveillance Program comprises of King Air's in the following locations:

- Comox, BC – One aircraft
- Halifax, NS. – One aircraft
- St. John's, NL – Two aircraft

With an annual utilization rate in excess of 7,000 hours per annum, no additional capacity exists within these aircraft to commence participating in missions in the North on a regular and dedicated basis. This is a good demonstration of the high level of utilization that is possible in a civilian private sector program that is working.

If the DFO Air Surveillance Program was chosen to provide aircraft to the North, it would likely require a minimum of two additional assets (one for each operating base, assuming two bases); and possibly not King Air 200's, mainly because of their limitation to paved runways. Although the geographic area is expansive and comprises significantly more coastline than both of Canada's east and west coasts combined, it is PAL's expert opinion that the approach of implementing two aircraft will provide for a cost-effective and operationally sound means of

[3] Cold-soaking refers to exposing an aircraft and equipment to long periods of very cold temperatures that can result in ice or frost build up, and/or possible malfunction of onboard systems (see Glossary).

executing 3,000 to 4,000 h/yr of dedicated surveillance presence in the North. Once this is accomplished and the data collection and enforcement presence requirements dictate it, another evaluation can be executed to determine if additional aircraft assets are required.

3.4 Bases of Operations

Would new bases of operation need to be established in the North, if so, what would the logistics considerations and cost estimates be (e.g. cost of new buildings, costs of fuel, skilled and unskilled manpower etc.)?

New bases of operation would likely need to be established in the North by a private operator for common infrastructure such as office space or hangarage. However, no additional airport infrastructure (e.g. runways) is required in the north to establish and accommodate a permanent air surveillance presence.

Hangarage for the purposes of transient aircraft traffic appears to be available and manageable in many communities across the North, including Resolute. However, except for Goose Bay there is an apparent lack of facilities that would lend themselves to permanent operations. This community has an over abundance of facilities that would be suitable to this type of operation. In a normal competitive bidding process, however, depending upon how proposals for the program are constructed, it is conceivable that existing facilities could end up being used or bid by private companies. Although Inuvik has sufficient hangars for existing general aviation operations, it is likely that new facilities are required to host a permanent additional aircraft to the area.

The cost of such a facility would clearly depend upon the size of the aircraft that hangarage is required for. It is also safe to suggest, however, that the cost to the Government of Canada will ultimately be dependent upon the duration of the contract; as with the other fixed capital assets in the program. In the case of the facility, cost considerations would include:

- Capital costs of the facility,
- Operating costs (e.g. heating, maintenance, etc.) and
- Residual value.

Perhaps the most challenging component of estimating the building cost would be the residual value (as low as $0). It is also important to note that a private company will not valuate the facility beyond the term of the contract unless it has other planned uses after the term. The market for the resale of hangars in the North may be evaluated as a high risk by private civilian companies, and therefore will likely pass the cost of such facilities directly through to the contracting Government department as part of a monthly basing fee.

There is always the possibility that a potential bidder on the program may have existing suitable facilities that otherwise would not be made available to another competing entity. In this case, it would remain advisable for Government to plan a budget that includes the operating, building and financing cost of new facilities in each base of operations. In a public tendering environment, a financial advantage may exist for a company that can arrange for existing hangarage. It is otherwise advisable for the Government to consider investing in the facilities and leasing them to the successful bidder. This will reduce the financial risk and thus cost to the Government.

There are several potential communities across the North that could be suitable candidates to establish main bases of operations:

- Goose Bay
- Inuvik
- Iqaluit
- Cambridge Bay

Other communities such as Resolute offer facilities, services and infrastructure that would be suitable for forward operations or fuel stops, but could not serve as a permanent base of operations.

In addition to the infrastructure costs of facilities, the total cost of providing the surveillance service can be divided into two main components:

1. the cost of providing day to day operations, such as:
    a. Buying fuel for the aircraft;
    b. Paying for flight crews, including mission equipment operators; and
    c. Paying for maintenance crews and any other ground personnel (this may include a food subsidy for all personnel).
2. The cost of capital purchases such as:
    a. The aircraft;
    b. The mission equipment, including spares; and
    c. Building any additional infrastructure that will be required, but may not be provided by the Government such as accommodation for employees if the local community is too small to absorb the additional population.

A private civilian operator, in a contractual relationship with the GOC, will be required to finance any capital equipment needed for the program that is not provided by the GOC. This introduces additional cost to the GOC and financing issues for the private service provider.

The private commercial company will evaluate the residual value of mission equipment extremely low which would result in more cost being passed back to Government. For example, if the private civilian company invests CDN$54.0M in airborne radar systems and spares, the residual value of the equipment in a 5-year contract is likely to be $0. Similarly, the residual value of the equipment in a 10-year contract is likely to be $0. The reason for the low residual values is linked to the fact that if the private civilian operator is unsuccessful in securing another contract for the mission equipment, then the resale value is potentially $0. The equipment is worth something if the operator is successful in securing another contract, but when considering financing for this type of program, it is a significant financial risk that the residual value is insufficient to pay for the original loads that were acquired to purchase the equipment in the first place. Therefore, it is in the best financial interest of Government to consider a contract term that maximizes the useful life of the mission equipment. To accomplish this, however, the tendering process should identify a requirement for "new" and modern technology.

In these capital intensive cases, however, it may be worthwhile for the Government to consider sufficient up-front funding to pay for the mission equipment and provide the equipment as Government Furnished Equipment (GFE) but with the civilian commitment to maintain it.

Providing a cost estimate for a surveillance program in the North is a detailed process that cannot be accurately described until all mission and infrastructure requirements have been clearly identified. However, the existing DFO Air Surveillance Program provided 7,166.10 surveillance hours in the 2006/2007 fiscal year for a total cost of $15,356,962. The average cost per hour was $2,143.

Considering a similar surveillance program in the North comprised of two Dash-8 series 106 type aircraft, performing approximately 4,000 h/yr, Provincial Aerospace estimates that this program would cost approximately CDN$20 million to CDN$25 million/yr, or $5,000 per hour. This estimate does not include the cost of facilities.

3.5 International Agreements

Are there currently any agreements with Greenland/Denmark that would allow us to fly surveillance over their waters, and possibly exchange information?

There are currently no agreements between Greenland/Denmark that would permit Canada to exchange surveillance information. However, it is known that DFO is currently and actively engaged in negotiations that would see the nations exchanging surveillance information on a regular basis for this specific area.

Flying over Greenland territorial waters (within the 12Nm zone) would be an issue for this type of program. The EEZ is a contiguous zone to the territorial sea and not an extension thereof. For example, "hot pursuit" can extend up to the territorial waters of Greenland, but no further. As a result, surveillance activities can occur in these areas.

Canada routinely flies over the contiguous Greenland EEZ zone when conducting patrols in the equidistance line area using the DND Aurora aircraft. Some consideration, however, should be given to the fact that the creation of a more frequent enforcement presence will inevitably create awareness at a political level within Denmark.

3.6 Cost Considerations

What would be some of the considerations, costs etc. for setting up a similar capability for the western approaches to Arctic Canadian waters such as the Beaufort Sea and Amundsen Gulf?

As suggested in Section 3.4 of this document, it is a general conclusion that two bases of operations are required to establish a level of surveillance and enforcement presence for the main entry points into Canada's Arctic. Although it is recognized that the western approaches for a significant portion of the year may be impassable due to the presence of ice, the execution of air surveillance missions in the general area contributes significantly to the documented expression of sovereignty of Canada's territory.

[4]Most of the cost considerations for setting up a base on the west coast would be very similar to those discussed in Section 3.4 with the possible exception of the base facilities and infrastructure. If a private company needs to add new facilities and infrastructure to the chosen site, at its own cost, then the effective cost per FH might increase because of the following two factors:

3. The potentially low residual value of the facilities and infrastructure (i.e. as low as $0); and

4. If fewer flight hours are required per year because only maritime surveillance is being pursued, and shipping is restricted to only a few months of the year due to ice coverage.

If, for the sake of conjecture, the additional facilities and infrastructure costs were $20M at the beginning of the contract, and the low residual value of the facilities and infrastructure is amortized over a contract lifetime of ten years, at 10% per year, compounded monthly, the total cost including principle and interest would be about $31.45M. Based on this amount, the additional cost per FH might not be considered very substantial. For example—again for the sake of conjecture—assume that only 2000 FH are required per year due to the shorter shipping period, therefore over the contract lifetime of ten years, the additional cost per FH would be estimated as:

Additional cost=$31.45M/(10yrs*2000FH)=$1572/FH.

[4] Note: this simple cost estimate performed by the Scientific Authority for illustrative purposes and may not be fully representative of the actual costs involved

4 Additional Considerations

4.1 Required Surveillance Hours Per Base

[5]How many hours of surveillance would be required from each base? (This may depend on the target types, sea vs. land.)

The determination of the required number of surveillance hours per base can be viewed from many perspectives yielding answers that could require an entire fleet of aircraft to be based in the North. Another factor to consider is the number of hours per aircraft and what constitutes a reasonable level of utilization for a surveillance aircraft for it to remain cost-, and operationally-effective.

For example, one could easily build a credible case that the extensive length of Arctic coastline, might require Canada to deploy over ten surveillance aircraft in the North to provide sufficient persistent coverage. The issue is not straight forward since it depends on first having a clearly defined set of requirements to address; however, in the paragraphs to follow, a case will be built to support the contention that as little as two aircraft may be sufficient to provide a solid airborne enforcement presence in Canada's North.

It is the suggestion of this document that two bases, each with one aircraft should be considered. Each base would cover the eastern and western approaches and choke points, and execute support to inland waters to the recently announced patrol ships.

Each aircraft should be planned to execute 1500 to 1750 h/yr. If the average mission duration was estimated to be 8 hours, then each aircraft would fly a mission approximately every 1.5 to 2 days. The aircraft are capable of executing more missions than this, however as the number of hours increases, so will the requirement for spares, especially for the mission equipment. In regular commercial operations, it is common to see annual aircraft utilizations in excess of 2,000 h/yr. However, it is not as common in the surveillance industry primarily due to the requirement for the mission equipment spares. Furthermore, as the requirement for mission hours increases, the operational impact of aircraft down-time due to serviceability issues becomes more apparent. In the 1,500 hour per aircraft scenario, an aircraft that is unserviceable "today" can reasonably be expected to execute the same tasking without impacting on other activities. However, as the required number of air hours increases, then the operational impact of aircraft downtime becomes more critical and at this point, another asset should be considered

As a comparative example, Canada's Aurora fleet was once capable of executing over 20,000 h/yr with an average 1,000 hours per aircraft. In the year 2006-2007, this fleet executed less than 7,000 h with an average of 333 h per aircraft. The DFO Air Surveillance Program with Provincial Aerospace executed over 7,000 h with 4 aircraft. However, at this utilization, there is no backup capacity and aircraft downtime must be kept to a minimum.

[5] Since actual GOC/DND requirements for arctic surveillance had not been specified at the time of the SOW for this contract, the answers to this question could only be based on the experience and expert opinion of the PAL contributors.

Mission equipment sparing is critical in the program, since specific components such as radars tend to have extremely long lead times. The successful selection of spares for the surveillance program will impact significantly on operations sustainment. A tendering process to the private sector should consider the contractors ability to understand which components of the mission equipment suite should be spared. For example, travelling wave tubes for X-band radars have nominal 9-month availability. Improper sparing of this type of component could easily result in aircraft downtime on the order of months. The point being made here is that surveillance operations require a combination of operations and support know-how, which already exists in Canadian industry.

To conclude, a reasonable approach could be considered to be one that commences operations by creating an initial and permanent airborne enforcement presence in the North with two aircraft performing approximately 1,500-1,750 h of surveillance activity each. Once the program is operational, additional assessments can be made based on the level of activity and aircraft utilization that comes from the presence of the surveillance asset.

4.2 Mission Endurance

What can be accomplished given the available air assets?

If all existing GOC air assets were to be considered for Northern operations, there would be little or no increase in enforcement presence. Transport Canada recently announced that the Canadian Ice Service (Dash-7) missions in the North would concurrently execute pollution missions. While this announcement contributes to increasing the utility of existing missions in the North, it does not noticeably increase airborne enforcement presence in the North, nor does it do anything to increase that presence in the critical approach areas. It also has to be recognized that the sensor equipment suite on the Transport Canada aircraft makes use of side looking airborne radar technology (SLAR) which is less than adequate for point target detection.

Existing DND assets are already overtaxed, and the increase in enforcement presence of these assets would likely have to result in a realignment of Force priority. It is known that the total flight hours for these aircraft is steadily declining to a point where fleet replacement is quickly becoming a significant issue.

The DFO Air Surveillance Program through Provincial Aerospace would have limited capacity using the existing air assets. The King Air 200 would be more restricted by runway conditions, availability of alternates and endurance. Although the program occasionally executes missions in the North, these tend to be for very short periods of on-station time, and usually are less than 1 hour on-task due to the significant distances between alternates.

As a result, Canada should consider the implementation of additional surveillance aircraft assets in the North. The mission endurance consideration should be in the 8-10 hour range which places the requirement within reach of several cost-effective aircraft platforms for the mission. These aircraft include platforms that the Canadian private industry have significant experience with including, but not limited to, the Dash-8 and the ATR-42. This mission endurance will be sufficient for aircraft to effectively execute missions in all areas of the North and, where necessary, make utilization of other locations such as Cambridge Bay for fuelling or for support of occasional forward operations. Technical aircraft issues such as endurance are manageable by Canadian industry, as for example, the Dash-8 is used commonly throughout the world with a fuel modification that would permit it to accomplish and in some mission profiles exceed the 8-10 hour mission endurance requirement.

Table 2[6] provides a list of several civilian aircraft platforms that could be used for northern surveillance and reconnaissance compared to the present Aurora MPA used by the CF. Most of the specifications quoted are, unless specifically noted, based on civilian versions used for passenger and/or cargo transportation.

Note that some of the range values provided in Table 2 should only be considered as relative estimates, since actual values depend on a number of factors such as the operational altitude, air speed, payload weight and fuel load. For example, according to [1] the maximum range for the King Air 200 at maximum cruise power, with maximum fuel, allowances for taxi, climb, descent, and 45 minutes of reserve fuel, varies between 2200 km and 3640 km at altitudes of 5485 m and10670 m respectively. The King Air B200T, which is a maritime patrol variant that is probably very similar to the PAL MPA, is stated to have a maximum endurance of 6.6 h or 1716 km (with 45 min. reserve) at a patrol air speed of 260 kph at an altitude of 610m. This variant can also be equipped with a long endurance fuel system consisting of two wingtip fuel tanks with a total capacity of up to 401 litres of fuel that can extend the aircrafts endurance to 9 hr, or 2340 km.

As shown in Table 2, the CP-140 Aurora has an operational range of between 7400 and 9266 km, probably due to changes in mission equipment (more equipment = less endurance/shorter range). While this may be more than three times the operational range of the King Air 200, its effective range is much less if it is deployed out of Comox BC, or Greenwood NS. Figure 8 and Figure 9 show possible routes that an Aurora might take to patrol the Northwest Passage if it was deployed from either Comox BC or Greenwood NS. Both flight paths assume the optimistic value of 9266 km for the Aurora's range endurance. Of the 8900 km path taken by the flight from Comox, only 4200 km represents an actual maritime patrol of the High Arctic. Similarly, the flight from Greenwood represents a flight of just less than 9200 km of which 7100 km is useful maritime surveillance, and only about 4500 km represents maritime surveillance in the Arctic, starting and ending near Baffin Island. As Addison states in [3] the Aurora's "… should also be forward deployed to Yellowknife or Iqaluit" in order to efficiently monitor the Arctic.

Although the King Air 200 has one of best endurance values of the civilian aircraft shown in Table 2, it is not equipped to land on unpaved gravel runways. This might significantly hamper its ability to perform maritime surveillance of the NWP since it could not stop at intermediate sites for refuelling and would need to return to its point of origin. As shown in Figure 10, even at optimistic ranges of 3400 km, if a King Air is based at either Iqaluit or Inuvik its area of responsibility would be constrained to less than half of the NWP. As shown in Figure 11, if the effective patrol range was reduced to just 2340 km its coverage on a single pass would be greatly reduced. Also, none of the flight paths shown in Figure 10 or Figure 11 allow for any loitering time over a particular target. However, if the primary mandate of the civilian MPA is to just patrol the approaches to the Arctic, since those waters remain open to sea traffic for a longer period of the year, the endurance of the King Air should not present a significant problem.

---

[6] The contents and references to *Table 2*, as well as content from this point to the end of Section 42 were inserted by the Scientific Authority and not vetted by the other authors.

Table 2: Potential civilian manned aerial surveillance platforms for the North compared with the CP-140 Aurora.

Aircraft	Range (km)	Cruise Speed (cs) (kph)	Max. Alt. (m)	Max. Fuel Weight (kg) without payload	Max. Fuel Weight (kg) with payload	Cabin Volume (m^3)	Baggage Volume (m^3)	Payload w/ max. fuel (kg)	Take-off Distance (m)	Landing Distance (m)
Dash-8 Q100	1889 (37 pass.)	491	7620		2576 (std) 4647 (opt)	37.6	8.3	3475	991	785
Dash-8 Q200	2084 (1713, 37 pass.)	535	7620		"	37.6	8.5	3389	1000	780
Dash-8 Q300	1711	532	7620		"	52.0	9.0	6124	1180	1040
Dash-8 Q400	2518 (70 pass)	667	7620		"	77.6	14.22	6831	1300	1287
King Air 200	3254 (max cs) 3495 (econ. cs) 2340 (patrol w/ extra tanks)	420 to 515 max (260 patrol)	10670	1,653 (2054 with wingtip tanks)	721	11.1	1.5		567	632
ATR-42	1556 (48 pass.) 2963 (max fuel)	555	7620	4500		58 (excl. flight deck)		5450	1165	1165
CP-140 Aurora	7400 to 9266	444 to 648 (max. =750)	10668					9000	1829	975

Information Sources:
Dash-8: [1], http://www2.bombardier.com/Used_Aircraft/en/Q_Dash_Specifications.jsp
www.aero.bombardier.com for Bombardier Q300 data sheet (June 2006), and Bombardier Q200 data sheet (June 2006)
King Air:[1], http://www.kingair.org/DataHistory/DataKA200.php
http://www.airliners.net/aircraft-data/stats.main?id=328
ATR-42: [1], http://www.aerospace-technology.com/projects/atr_42 /specs.html
CP-140 Aurora:[1], [2], www.airforce.forces.gc.ca/v2/equip/cp140/specs-eng.asp and www.p3orion.nl/tech.html

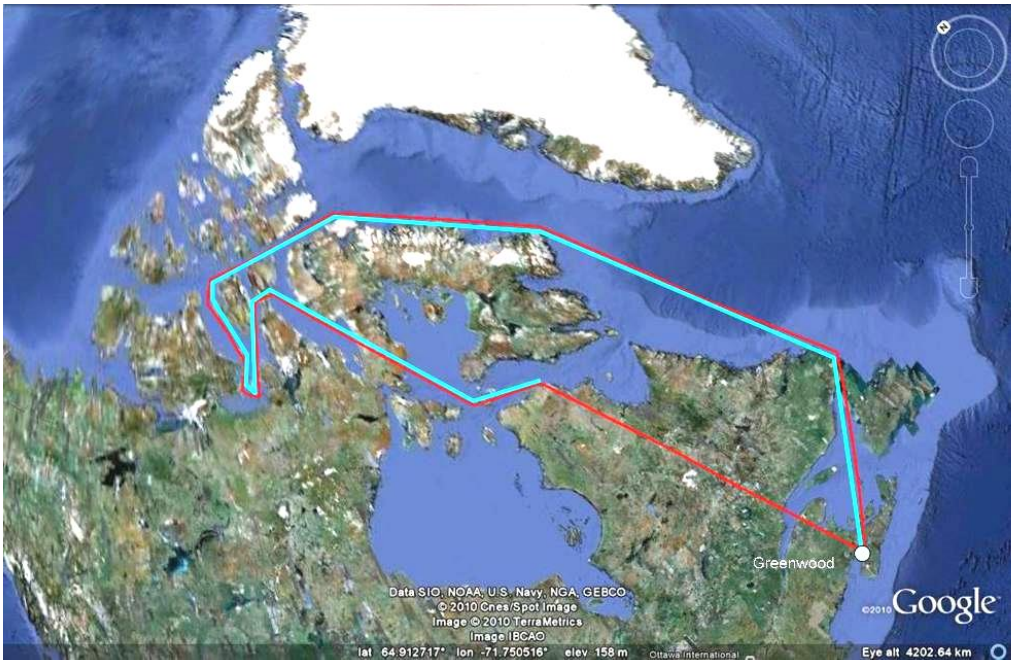


Figure 8: Notional patrol route for a CP-140 deployed from Greenwood NS to perform a tour of the High Arctic. The path in red represents a route that takes up almost 9200 km whereas the light blue path represents the portion that is useful for maritime surveillance 7100 km.

Figure 9: Notional patrol route for a CP-140 deployed from Comox BC to do a tour of the High Arctic. The path in white represents a route that takes up almost 8900 km whereas the light blue path represents the part of the portion that is useful for maritime surveillance, 4200 km.

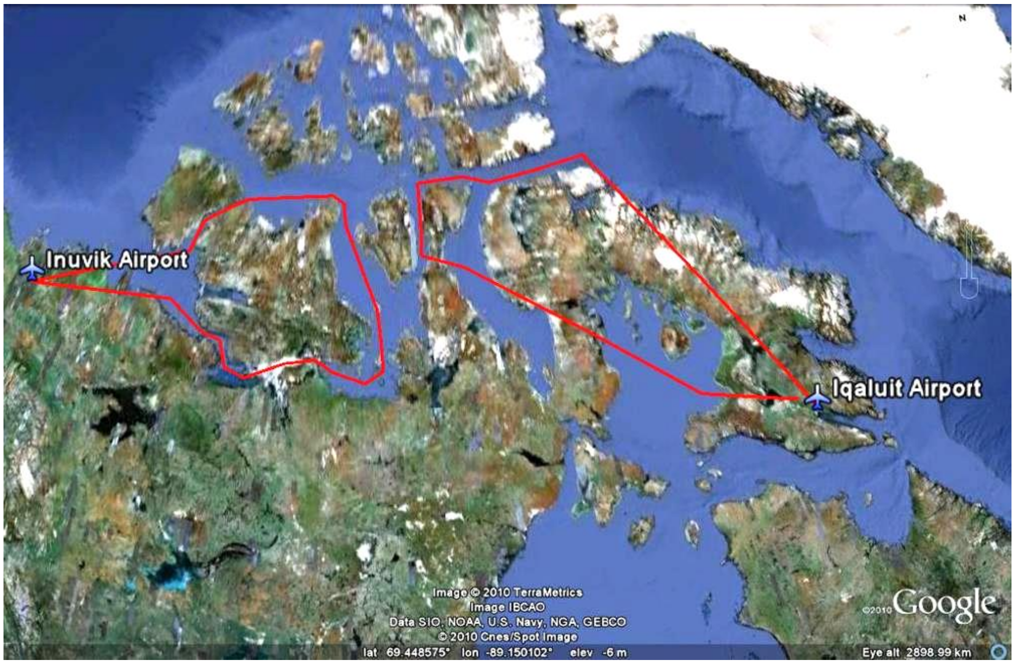


Figure 10: This map shows potential flight paths (red line) for a King Air that would require a range of at least 3400 km when flown out of either Inuvik or Iqaluit airport.

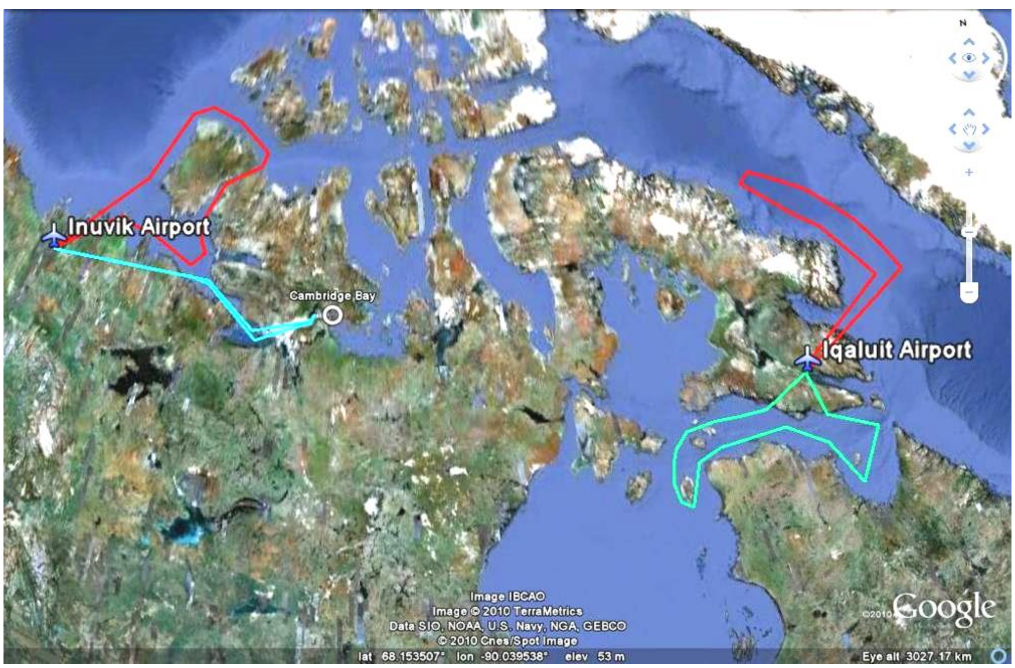


Figure 11:This map shows how the flight paths for a King Air would be significantly restricted if it only had a range of 2340 km (i.e. flying at 610 m for 9 h at 260 kph). The different colours represent different 9 hour surveillance routes.

Viable alternatives to the King Air might be the Dash-8 or ATR-42; they would be able to take advantage of numerous gravel landing strips (with fuel service) to greatly extend their range. For example, the unpaved runways at Resolute, Nanisivik, and Hall Beach have all been used by First Air, the main commercial passenger service between Iqaluit and Resolute. Figure 12 shows all of the communities served by First Air as part of their normal service routes. The possible disadvantage of using these larger aircraft is that their fuel load is correspondingly greater, thus increasing the per-hour flight costs.

Figure 12: Arctic communities served by First Air

4.3 Enforcement Presence Frequency

At what rate can a given AOI be revisited?

Enforcement presence frequency will also be determined by some of the factors discussed in Section 4.2 regarding mission endurance and air hours. It will also be determined by the requirement to provide operational support to the planned Arctic Offshore Patrol Ships (AOPS). Otherwise, the aircraft should be creating frequent enforcement presence into the choke points of the North along the western and eastern approaches. Complete 100% coverage for both day and night would be an expensive consideration and alternatives would have to be considered. However, a more realistic approach would be to create an initial enforcement presence, perform an additional assessment once more information has been collected, and then ascertain if additional presence is required. Otherwise, it is suggested that the aircraft should be deployed on a daily basis as much as possible. However, as discussed in Section 4.1 some consideration should be given to the fact that as operations increase, the operational impact on aircraft downtime becomes more significant, but can be mitigated through the implementation of additional aircraft.

As alluded to in the previous section, an additional factor to consider is the fact that with the exception of heavy ice-breakers the NWP is currently closed to most shipping, during a significant portion of the year. Although shipping conditions within the Arctic Archipelago (i.e. NWP) during the year will vary depending on the specific location, annual variations, seasonal variations, and in some cases even diurnal variations, as well as the vessel type, the main shipping season has typically been accepted as being from mid-July to late September/mid-October. The rules governing shipping access to different areas of the Arctic for different periods of the year have typically followed the Zone/Date system (see Annex B) or the Arctic Ice Regime Shipping System used by Transport Canada [4] and the Canadian Coast Guard [5]. Assuming that this continues to be the case, and is not significantly altered by global climate change within the next decade or two, any requirement for maritime surveillance in the NWP would just be limited to approximately a two to three month period during the year. Since the availability of open shipping routes expand and contract depending on the season, this will probably have an impact on (i.e. increase) the revisit rate that an air platform can afford to assign to a given area within the overall AOI shown in Figure 2. On the other hand since maritime surveillance is not required year-round this might have an impact on the ability to retain pilots and technical support staff on a year round basis unless they continue to be used for other surveillance purposes.

4.4 Mission Equipment Suite

What should the mission equipment suite consist of? (This may depend on the air asset, e.g. King Air, Dash 7/8, UAV);

For the maritime environment that also has a requirement for land based enforcement presence and surveillance, there are many requirements that should be identified, including the following:

- Long range detection of surface vessels;
- Detection of surface pollutants;
- Positive identification of ships at night;
- Classification of targets of interest at night;
- When required, create enforcement presence or remain covert;
- Communication; and
- Documentation.

To accomplish these requirements, the aircraft should, at minimum, be equipped with the capabilities listed in the following paragraphs:

- Airborne search radar – An X-band multimode radar system, like the one shown in Figure 13, would be required for this type of mission. At a minimum it should include sea search, track-while scan, Synthetic Aperture Radar (SAR), Inverse SAR (ISAR), Strip SAR, weather mode, etc. Modern multimode radars provide all of the functionality and modes that are suitable for both land and sea applications for the detection, classification and tracking of targets including oil spills. As implied by the photo of the surveillance equipment aboard a typical PAL surveillance shown in Figure 13, Canadian industry has the experience and expertise to work with and operate multimode radars.

Figure 13: The private sector in Canada has significant experience with owning, operating, and maintaining modern X-band multimode radars (see display, upper left).

- Forward looking infrared – The aircraft should also be equipped with a gyrostabilized forward looking infrared system with a spotter scope, wide angle color CCD video camera and an infrared video camera
- Tactical system – At the heart of the aircraft mission equipment suite should be a tactical system, capable of integrating sources of point target information onboard the aircraft
- Photography system – To provide high resolution images of commercial ships and other targets as required
- Communications systems – The communications suite should cover the standard communications frequencies, along with SATCOM for satellite communications
- IR/UV scanner – This technology would prove useful in the event of an oil spill in the North that required high resolution mapping of the incident to contribute to cleanup and assessment operations.
- Drop capabilities – The aircraft should be equipped with the capability to deploy stores such as life rafts, smoke markers, sonobuoys and oil sampling devices.
- ESM/ELINT – The aircraft should also be capable of collecting electronics intelligence information and be capable of forwarding this information to DND. It will contribute significantly to the construction of ELINT information on commercial, military, and other emitting sources in the North whether they are on the sea or on land.
- IMINT – The program could also optionally consider a long range IMINT (imagery intelligence) capability for the aircraft. Conditions exist in the north where IMINT systems

can produce quality imagery from significant distances in excess of 50nm (92.6 km) from aircraft.

- Night-time identification system – The ability to detect, classify and identify targets of interest during daylight and darkness is equally important, at least in more southerly latitudes, i.e. below 55°N. As illustrated by Figure 14, most year-round shipping on the east and west coasts fall into this category and surveillance must be carried out in either daylight or darkness on a daily basis. However, in the Arctic, open-sea shipping is closed for a significant portion of the year to most vessels, and diurnal day/night scenarios with full darkness only start to occur later in the shipping season. On the other hand, if both land and maritime surveillance is required, then the importance of night-time imagery is increased. For night-time operations, the creation of enforcement presence and the acquisition of positive identification can be accomplished using either near infrared laser illumination systems or visible flash technology. Near infrared systems are commercially available, but have the disadvantage of being applicable to ships with identifications that have large letters, but offers the advantage of supporting covert operations where necessary. The use of visible flash technology will contribute to any requirement for creating an overt enforcement presence and provides high quality, color imagery of targets of interest in complete darkness. The picture in Figure 15 is an example of visible-spectrum flash photography for night-time operations.

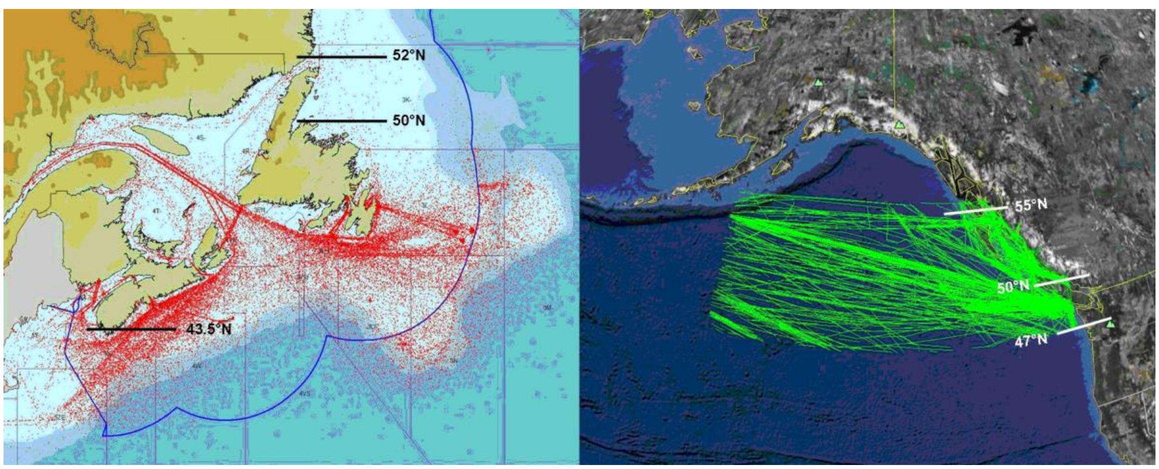


Figure 14: The left map (courtesy of PAL) shows a 1-yr composite (red dots) of commercial vessel traffic on Canada's east coast whereas the left (from the unclassified RMP) shows vessel tracks for the west coast (green lines) for just 10 days (29 Aug. – 8 Sept.). When the North opens up, will the Labrador coast look similar?

Figure 15: Actual photograph taken in complete darkness from a Provincial Aerospace surveillance aircraft during a routine DFO mission using visible spectrum flash photography. [Photo courtesy of Provincial Aerospace Ltd]

4.5 Mission Profiles

What is the potential for splitting costs among various participants in a multi-role mission given that the lead agency might be DFO, DND or some OGD?

On the surface, it makes sense that OGD's should be capable of managing costs among participants for multi-role missions. However, the financial model for these types of programs is usually comprised of a fixed monthly fee, and then a nominal hourly recurring rate. Therefore, even though two different departments may share the costs of a single mission, this does not accurately reflect the total program delivery cost. For example, the hourly rate in the DFO Air Surveillance Program (ASP) is $836.00 per hour, plus an additional monthly basing fee. When OGD's participate in missions, the hourly rate does not contribute to the fixed costs of the program.

The important point to consider is that the lead contracting agency assumes the burden of the fixed costs of the program (e.g. equipment) and would likely be sensitive to the increased flying hours provided to OGD, especially if it impacts on aircraft availability. However, to date this problem has not been encountered in the DFO ASP, and OGD's do participate in the direct use of the aircraft including DND, RCMP, TC, and CIS.

PAL surveillance flights, originally focussed on DFO fisheries patrols, may need to accommodate other activities such as Search and Assist, as shown by the photograph in Figure 16.

Figure 16: OGD's and agencies such as Rescue Coordination Centre (RCC) take advantage of the aircraft availability for mission profiles such as Search and Assist. [Photo courtesy of Provincial Aerospace Ltd]

Worthwhile consideration should be given to the Australian model, in which one government agency accepts responsibility to coordinate the air surveillance requirements of the various government departments.

DFO is an agency capable of executing this type of coordination, and has the multi-agency experience in the maritime enforcement business. The Conservation and Protection Branch of DFO is one of the very few Departments that has exercised enforcement activities on the Canadian high seas and has the experience and know-how. The advantage of considering DFO as a lead agency is that it already engages in surveillance activities including the use of a highly successful private sector model through the public tendering system with Provincial Aerospace Ltd. of St. John's, NL. It is equally important to note that both DND and DFO have had a long history of working collaboratively to achieve operational effectiveness for their mission mandates.

The DFO ASP has been highly successful at maintaining and growing the program in the past decade mainly due to the fact that the Department remains sensitive to the data and enforcement presence requirements of OGD's.

One has to consider what the potential implications are for the long-term sustainment of a Government operation if that Department is engaged in activities that are of notable financial magnitude that otherwise the Department has no mandate for. This can create a very challenging situation for a Department that may potentially face (as all do) a reduction in operating budget. A program such as the DFO ASP should remain with a single Government department, but some consideration could be given to formal recognition of the additional mandates through legislation.

4.6 Primary Targets of Interest

What would be considered the most important targets of interest?

For a new Northern Surveillance effort, there are several potential targets of interest that the GOC should consider to be of interest. These include:

- Commercial vessels;
- Research vessels; and
- Fishing vessels.

Other imaging technology should also be considered for the detection of land based targets for applications such as:

- Change detection; and
- Ground vehicle detection.

4.7 Suitability of Alternates

Are there sufficient and suitable alternative airstrips available for aircraft that cannot return to their origin for whatever reason (e.g. inclement weather)?

The Canadian North has sufficient alternates available for surveillance operations and aircraft that have approximately 8-10 hour endurance, regardless of whether they require a paved surface. Information on this can be found in Sections 4.10 and 4.12.

4.8 Forward Operating Bases

Should main bases be augmented by occasional forward operating bases (overnights); i.e. would full-time presence in the Arctic be necessary, or could the necessary presence and surveillance be accomplished with occasional flights from a southern base (similar to CF Maritime Patrol Aircraft patrols)?

A full-time presence of surveillance aircraft in the Arctic will be necessary for the western approaches. As suggested earlier, Inuvik is a strategic location that can easily and readily provide frequent air surveillance presence in the west and at the same time provide frequent support to patrol ships based out of Cambridge Bay and operating in the Northwest Passage. The lack of shipping activity for extended periods of time throughout the year would not necessarily preclude the requirement to have regular enforcement presence depending upon the mission priority. The overt presence of an enforcement platform is in itself an expression of sovereignty. If sovereignty is identified as a requirement, then the frequent presence of the aircraft over vast amounts of

Canadian northern territory is a valuable approach to establishing a full time presence in the Arctic.

Occasional flights from the main bases of operations (Goose Bay, Inuvik) can be deployed into the higher regions of the north, including Resolute Bay, Thule AFB, and Alert (see Figure 17). Resolute Bay, and in particular Thule AFB, both offer excellent potential to act as occasional forward operating bases.

Figure 17: Missions can occasionally be deployed into the High Arctic by making use of forward operating bases such as Cambridge Bay, Resolute, Thule AFB and even Alert. The thick red arrow indicates how such bases could occasionally be used to extend the surveillance coverage of a single aircraft. However, since Resolute and Alert have unpaved surfaces, appropriate aircraft would be needed (e.g. not a King Air).

4.9 Ice Flows

What effect might ice flows have on the ability to carry out surveillance efforts?

The presence of pack-ice flows in the North will impact on the presence and level of target activity in the area of responsibility, but will have minimal impact on the efficiency of the surveillance missions. The aircraft will be equipped with sufficient sensors and technology to be able to detect, classify and identify targets of interest even in pack ice. Although more challenging for the sensor operators, the presence of ships in ice can be detected using modern multi-mode radars. Long range detection can also occur using the IR imager as the contrast in this spectrum between the ship and surrounding environment is significant.

Modern multimode radars have the normal point target detection capability that can prove to be very challenging when employed for detecting targets in pack ice. However, when normal search modes are combined with mature ISAR, SpotSAR (Spot Synthetic Aperture Radar) and Electronic Support Measures (ESM) or Electronic Intelligence (ELINT) capabilities, the ability of the surveillance crew to detect targets in pack ice is significantly increased.

Since ice thickness will impact on the presence of shipping activity, an evaluation of the value of having a reduced enforcement presence in these areas at such times should also be considered. One such approach would be to reduce the frequency into those areas throughout the year where pack ice prevents the normal movement of ships.

4.10 Fuel Services

What is the availability of 24/7 services such as fuel?

Fuel is seldom available on a 24 hour per day, 7 day per week basis, except under special circumstances, and assuming it is even available at all. Table 3[7] (Illustrated in Figure 18) is a list of all airports at latitudes north of 60°N [8]that have any services available, including refuelling facilities. It is a subset of *Table 4* shown later in section 7.12 Runway Conditions. It can be seen from the list that when fuel is available, it comes in a variety of forms, which may not be compatible with all aircraft.

Table 3: Airport services available at airports in Northern Canada

Location	Fuel	Oil	Services						ARFF
			S1	S2	S3	S4	S5	S6	
Alert (CFB)	PPR								18-24m
Arviat	DFA, JB, 100LL							X	
Baker Lake	100LL(D), JB					X	X	X	
Beaver Creek						X	X	X	
Burwash Landing						X	X	X	
Cambridge Bay (NWS)	100LL(D), JA-1,hpr							X	
Cape Dorset	JA-1					X		X	
Carcross						X	X		
Carmacks						X		X	
Chesterfield Inlet	DFA,								
Clyde River	JA-1								
Coral Harbour	JA-1,							X	
Cousins (Yellowknife)						X			
Dawson (City)	100LL, JB	80, 100				X		X	
Edzo –Fort Smith						X			
Faro	100LL, JB					X	X	X	
Fort Simpson	100LL, JA-1,					X		X	

[7] Note, all content and material referencing Table 3 were provided by the Scientific Authority.

Location	Fuel	Oil	Services						ARFF
			S1	S2	S3	S4	S5	S6	
	SP, HPR								
Fort Smith	100LL, JA-1	BP2380 15W30		X		X		X	
Gjoa Haven (NWS)	JA-1								
Grise Fiord	JA-1								
Haines Junction						X	X	X	
Hall Beach (NWS)	JA-1								
Hay River	100LL, JA-1	All	X	X	X	X	X	X	
Holman/ Ulukhaktok	JA								
Igloolik	JA-1								
Inuvik	100, JA-1, HPR	15W30	X	X		X		X	
Iqaluit	100LL, JA-1	All							24-28m
Ivujivik	DFA, 100LL(D),								
Kangiqsujuaq	100LL(D), JA-1								
Kangirsuk	100LL(D), JA-1								
Kasba Lake	100, JA					X			
Kugaaruk	DFA								
Kugluktuk	100LL(D), JA-1								
Mayo	100LL, F-34, JB					X	X	X	
Nanisivik	JA-1, HPR							X	
Norman Wells	100LL, JA-1, HPR,	All				X		X	
Pangnirtung	JA-1								
Paulatuk	JA								
Pelly Crossing						X			
Pine Lake						X			
Pond Inlet	JA-1,								
Puvirnituq	100LL(D), JA-1,								
Qikiqtarjuaq	JA-1,								
Rankin Inlet	100LL(D), JA-1, HPR								
Repulse Bay	DFA								
Resolute Bay	JA-1		X	X		X	X		
Sach's harbour	JA								
Salluit	100LL(D), JA-1								
Silver City						X			
Taloyoak	JA-1	ALL							
Teslin						X	X	X	
Trout Lake						X		X	
Whale Cove	DFA								

Location	Fuel	Oil	Services						ARFF
			S1	S2	S3	S4	S5	S6	
Whitehorse	100LL, F-34 JA-1, HPR	ALL	X	X		X	X	X	24-28m
Wiley	100, F-34								
Yellowknife	100, 100LL, JA-1, F-34, HPR	ALL	X	X		MIL X			28-39m

Fuel Codes:
100 = Red Aviation Gas (AVGAS) 80/87
100 = Green AVGAS 100/130
100LL= Blue AVGAS 100
JA = Turbine Fuel-Kerosene Type Jet A (no FSII)
JA-1 = Turbine Fuel- Kerosene Type- ASTM-Jet A-1
JB = Turbine Fuel-Wide cut Jet B
F-34 = Turbine Fuel-Kerosene Type-FSII
DFA = Diesel Fuel (no FSII)
(D) = Available from drum only
HPR = High Pressure Refuelling
FSII = Fuel System Icing Inhibitor
SP = Single Point Refuelling
PPR = Prior Permission Required

ARFF = Aircraft Rescue and Fire Fighting
X = denotes availability of service
S1= Storage
S2= Servicing/Minor Repairs
S3= Major Repairs
S4= Extended Term Parking
S5= Tie Down Facilities
S6= Plug-in Facilities

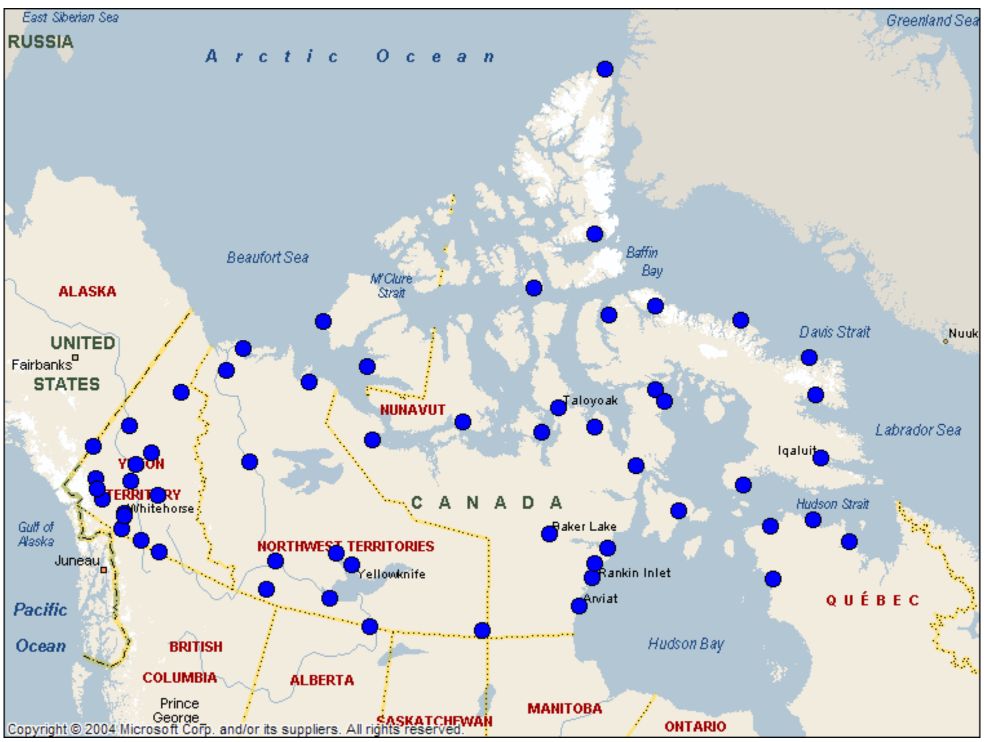


Figure 18[8]: Map of airport locations of airports in Northern Canada with some services available; based on data from Table 3.

[8] Note, Figure 18 was created and inserted by the Scientific Authority

4.11 Hangarage

What kind of aircraft support infrastructure might be expected throughout the Arctic (e.g. availability of hangars for shelter and maintenance)?

The identified key and potential main bases of operations have varied facilities. Although Goose Bay has significant infrastructure, much of this is not private sector "friendly" as the majority of the facilities are, simply put, huge and would be cost-inefficient to operate. However, facilities in Goose Bay are available on a negotiated basis, such as, but not limited to, Hangar 14, which is quite possibly the most commercially viable facility in Goose Bay. Otherwise, challenges do exist for Inuvik. The majority of the existing facilities are sufficient for transient use or for use by their respective owners for their own Northern general aviation operations. As a result, if Inuvik was chosen as a permanent base of operations, then it is likely that a new facility would have to be constructed.

Otherwise, for forward operating bases, sufficient infrastructure exists to facilitate the occasional forward deployment of surveillance aircraft. These missions would have to be planned in advance to ensure the availability of hangarage as it is inadvisable to cold-soak surveillance aircraft.

4.12 Runway Conditions[9]

What kind of runway conditions can be expected throughout the Arctic?

The sparse population in the Arctic means that commercial air traffic for the transportation of goods and passengers is not very high. Therefore, aside from exceptional cases, it is difficult to justify and support the high infrastructure costs required for the installation and maintenance of paved runways for fixed-wing aircraft. As a result, most aircraft landing areas throughout the Arctic are fairly rudimentary. Most runways for fixed wing aircraft that are capable of operating year round are usually unpaved with surfaces consisting of various combinations of gravel, clay and turf. Some other landing areas include seaplane bases or seasonal runways over frozen lake surfaces. The simplest landing areas may just consist of a relatively flat expanse of land marked by old fuel barrels requiring little or no maintenance, but also having little or no support facilities either. A good example of such a landing strip is the one pictured in Figure 19, used by DRDC at Gascoyne Inlet on the Southwest coast of Devon Island. As shown in the picture, such strips are usually just long enough and flat enough to suffice for a short take-off and landing (STOL) DHC-6 Twin Otter, equipped with specially designed tires to handle the rough terrain.

[9] Note, most of the content of this section was researched and provided by the Scientific Authority.

Figure 19: Short gravel runway at Gascoyne Inlet used by DRDC to access a small camp there. The special tires of the Twin Otter allow it to easily land and take off from such a rough strip consisting of sharp broken shale, with numerous depressions like the one in the foreground [photos by D. Brookes, 2008]

Figure 20 is a map of the known land based runways in Canada (also listed in *Table 4*) north of latitude 60° N. The list in *Table 4* contains both active (unshaded) and closed runways (shaded grey). Some are located near communities, current or former mining or construction sites, and at North Warning (Radar) System installations or former Defence Early Warning (DEW line) sites. Seaplane bases were not considered because it is assumed that they would not be able to support and maintain aircraft with a suite of expensive surveillance sensors. The population estimates in *Table 4* where obtained from the Community Profiles of the 2006 Census figures provided on-line by Statistics Canada [6] and the runway locations were obtained from a downloadable database of sites provided on-line [7]. These runway locations and lengths were all confirmed, to the extent possible, using the January 2007 Canada Flight Supplement [8], and the satellite photos available on Google Earth, a Geographic Information System (GIS) which, in its most basic version, is freely available.

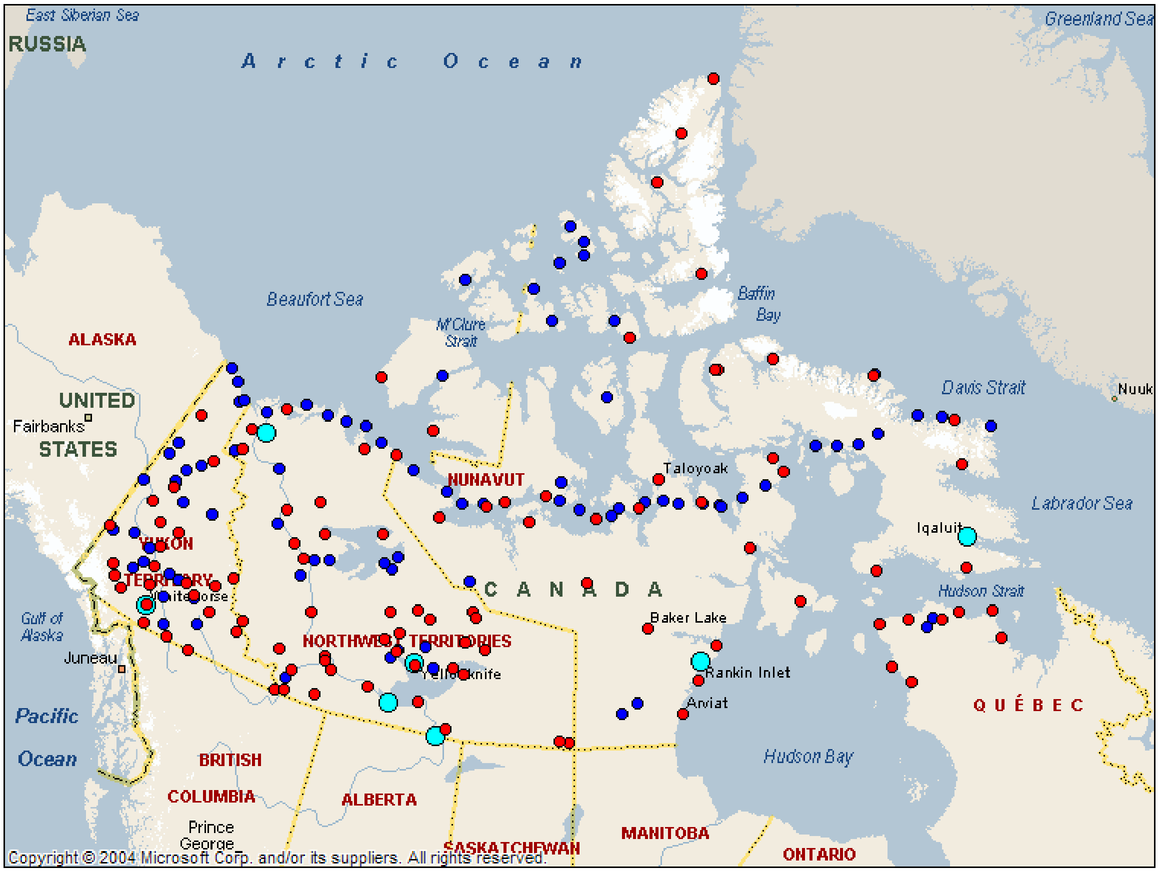


Figure 20: Land based airports and runways in northern Canada based on data from Table 4; the dark blue dots represent closed airports, whereas the red ones represent open unpaved runways and the light blue represent airports with paved landing strips.

Table 4: Land based runways located north of 60°N for fixed wing aircraft. Shaded sites denote closed runways whereas the unshaded locations represent open airports or runways as of 2007.

Location	Length (m)	Surface Type	Population (2006 census, Statistics Canada)	Latitude(°N)/ Longitude(°W)
Aishihik	1850	gravel	N/A	61.65000153/137.4833374
Aklavik	914	gravel	594	68.223297/135.005997
Akulivik	1050	gravel	507	60.8185997/78.14859772
Albert Bay	unknown	unknown	N/A	69.6333313/103.6166687
Alert (CFB)	1527	gravel	N/A	82.517799/62.280602
Anderson Point	unknown	unknown	N/A	68.21666718/87.91666412
Arctic Bay	440	gravel	690	73.005302/85.033096
Arviat	1320	gravel	2060	61.09420013/94.07080078
Atkinson Point (DEW)	700	gravel	N/A	69.93333435/131.4166718

Baker Lake	1285	gravel	1728	64.29889679/96.07779694
Bear River	950	gravel	N/A	64.81666565/134.2666626
Beaulieu River	unknown	unknown	N/A	62.45000076/113.0333328
Beaver Creek	1027	gravel	112	62.410301/140.867004
Bennett Field	1800	gravel	N/A	65.03333282/124.6666641
Bernard Harbourt (NWS)	950	gravel	N/A	68.7553/114.939
Blow River	930	gravel	N/A	68.78333282/137.4499969
Braeburn	1370	gravel	1286	61.484402/135.776001
Bray Island (NWS)	1230	gravel	N/A	69.2357/77.2735
Burwash Landing	1524	gravel	73	61.371101/139.041000
Byron Bay (DEW)	1380		N/A	68.75/109.0666656
Cambridge Bay (NWS)	1530	gravel	1477	69.108101/105.138000
Camsell River (Terra Mining)	1450	gravel	N/A	65.6166687/118.1500015
Cape Christian	200	gravel	N/A	70.51667023/68.30000305
Cape Dorset	1250	gravel	1236	64.23000336/76.52670288
Cape Dyer (NWS)	1400	gravel	N/A	66.59999847/61.56666565
Cape Hooper (NWS)	unknown	unknown	N/A	68.46666718/66.83333588
Cape Parry (NWS)	1720	gravel	N/A	70.1669/124.694
Cape Young (DEW)	1200	gravel	N/A	68.935/ 1116.934
Carcross	835	gravel	331	60.17419815/134.697998
Carmacks	1820	Gravel	425	62.108101/136.179993
Casino	821		N/A	62.7203/138.81
Chapman Lake	830	gravel	N/A	64.900002/138.266998
Chesterfield Inlet	1200	gravel	332	63.34690094/90.73110199
Clifton Point (DEW)	1280?	Gravel	N/A	69.2167/ 118.633
Clinton Creek	1500		N/A	64.46666718/140.7333374
Clinton Point (DEW)	1500	gravel	N/A	69.5833/120.746
Clyde River	1190	gravel	820	70.486099/68.516701
Colomac	1500	gravel	N/A	64.38500214/115.125
Colville Lake	750	gravel	126	67.033302/126.083000
Coral Harbor	1500-1800	gravel	769	64.1933/ 83.3594
Cousins	1100	gravel	(see Whitehorse)	60.808102/135.177002
Crooked Lake	unknown	unknown	N/A	72.66666412/98.5
Cullaton Lake	unknown	unknown	N/A	61.31666565/98.5
Déline	1199	gravel	525	65.211098/123.435997
Dawson (City)	1524	gravel	1327	64.043098/139.128006
Dewar Lakes (NWS)	1380	gravel	N/A	68.6264/71.1262
Diavik	1580	gravel	N/A	64.51139832/110.2890015
Discovery	750	gravel	N/A	63.18333435/113.9000015
Donaldson (Kattiniq)	1900	gravel	N/A	61.66220093/73.3214035
Doris Lake	unknown	unknown (ice?)	N/A	68.12527466/106.5852814
Drake Point	unknown	unknown	N/A	76.46666718/108.7333298
Edinburgh Island (NWS)	450	gravel	N/A	68.4859/110.864
Edzo –Fort Smith	1080	gravel	339	62.766701/116.084000
Ekati	1920	gravel	N/A	64.69889832/110.6149979
Esker Lake	unknown	unknown	N/A	61.65000153/74.66666412
Ekati	1475	gravel	N/A	79.994698/85.814201
Faro	1219	gravel	341	62.207500/133.376007

Finlayson Lake	580	gravel	N/A	61.691399/130.774002
Ford Bay	1000	gravel	N/A	66.037498/124.714996
Fort Good Hope	914	gravel	557	66.240799/128.651001
Fort Liard	910	gravel	583	60.2358017/123.4690018
Fort McPherson	1067	gravel	776	67.407501/134.860992
Fort Providence	1150	gravel	727	61.319401/117.606003
Fort Resolution	1219	gravel	484	61.180801/113.690002
Fort Simpson Island	1080	gravel	1216	61.866699/121.365997
Fort Simpson	1829	paved	(see above)	61.760201/121.237000
Fort Smith	1800	asphalt	2364	60.02030182/111.961998
Gahcho Kue	unknown	ice	(private airport for De Beers Ca.)	63.43305588/109.1997223
Gjoa Haven (NWS)	1360	gravel	1064	68.635597/95.849701
Gladman Point (NWS)	1500 (1461)	gravel	N/A	68.6629/97.7971
Grant Point	unknown	unknown	N/A	68.40000153/98.65000153
Great Bear Lake	1500	gravel	N/A	66.70310211/119.7070007
Grise Fiord	580	gravel	141	76.426102/82.909203
Hall Beach (NWS)	1580	gravel	654	68.776100/81.243599
Hat Island (NWS)	1000	gravel	N/A	68.309/100.063
Haines Junction	1524	gravel	589	60.789200/137.546005
Hart River	unknown	unknown	N/A	64.66666412/136.8333282
Hay River	1800	asphalt	3648	60.83969879/115.7829971
Henik Lake	1270	gravel	N/A	61.65000153/97.3666687
Holman/ Ulukhaktok	1400	gravel	398	70.762802/117.806000
Malloch Hill/Horton River (NWS)	365	gravel	N/A	70.01667023/126.9499969
Hyland	1146	gravel	N/A	61.523899/128.268997
Igloolik	1300	gravel	1538	69.364700/81.816101
Inuvik	1780	asphalt	3484	68.3039/133.484
Iqaluit	2600	asphalt	6184	63.756/68.5545
Isachsen	1200		N/A	78.78333282/103.5500031
Ivujivik	1100	gravel	349	62.4172/ 77.9253
Jean Marie River	762	gravel	81 (near Fort Simpson)	61.516701/120.616997
Jenny Lind Island (NWS)	1400	gravel	N/A	68.6571/101.743
Johnson Point	unknown	unknown	N/A	72.76667023/118.5
Kangiqsujuaq	1190	gravel	605	61.5886/71.9298
Kangirsuk	1200	gravel	466	60.02719879/69.99919891
Kasba Lake	1900	gravel	N/A	60.29190063/102.5019989
Keith Bay (DEW)	Unknown	unknown	N/A	68.25/88.15000153
Ketza River	unknown	unknown	N/A	61.84999847/132.300003
Kimmirut (Lake Harbour)	600	gravel	411	62.8482/69.8776
King Christian	1500	gravel	N/A	77.76667023/101.0333328
Kivitoo, (DEW)	880	gravel	N/A	67.9323/64.8691
Komakuk Beach (NWS)	1050	gravel	N/A	69.5964/140.176
Kugaaruk	1653	gravel	N/A	68.534401/89.808098
Kugluktuk	1650	gravel	1302	67.8168/115.145
La Biche River	1740	gravel/ turf	N/A	60.12919998/124.0490036

Lady Franklin Point (NWS)	1400-1550	gravel	N/A	68.4752/113.22
Liard Construction	unknown	gravel	N/A	65.08333588/138.366668
Little Salmon	600	gravel	N/A	62.18333435/134.8833313
Livingstone	1700	gravel	N/A	61.36666489/134.3666687
Longstaff Bluff	1270	gravel	N/A	68.93333435/75.28333282
Lougheed Island	unknown	unknown	N/A	77.44999695/105.0833359
Lupin	1400		N/A	65.76667023/111.25
Lutselk'e	913	gravel	318	62.418301/110.681999
Mackar Inlet (DEW)	unknown	unknown	N/A	68.34999847/85.73332977
MacMillan Pass	771	gravel	N/A	63.181099/130.201996
Magda Lake	unknown	unknown (ice?)	N/A	72.41666412/82.41666412
Magundy	1100	gravel	N/A	62.16666794/133.983337
Mallard	1200	gravel	N/A	65.8247/140.193
Malloch Dome	unknown	unknown	N/A	78.21666718/101.0500031
Matheson Point	1000	gravel	N/A	68.81666565/95.28333282
Mayo	1480	gravel	248	63.616402/135.867996
McQuesten	1500	gravel	1286	63.599998/137.567001
Midway	1150	gravel		67.23332977/135.300003
Mile 102 Dempster Highway	unknown	gravel	N/A	65.1166687/138.3333282
Mile 129 Mackenzie Highway	900	gravel	N/A	62.5/116.4833298
Mile 203 Dempster Highway	700?	Gravel	N/A	66.1166687/137.25
Minto	1370	gravel	296	62.604722/137.221944
Mould Bay	1000	gravel	N/A	76.23332977/119.3166656
Mount Flett	1500	Gravel/ turf	N/A	60.66666794/123.5999985
Mount Nansen 6	unknown	unknown	N/a	62.01666641/137.066665
Mountain River	1800	gravel/ turf	N/A	65.68333435/128.8166656
Nahanni Butte	890	gravel	115	61.029701/123.389000
Nanisivik	2000	gravel	0 (?)	72.982201/84.613602
Nicholson Peninsula (NWS)	1000	gravel	N/A	69.94999695/128.8833313
Norman Wells	1828	paved	761	65.281601/126.797997
North of Sixty/ Obre	1800	gravel	N/A	60.31639862/103.1289978
Ogilvie River	1050	gravel	N/A	65.666702/138.117004
Old Crow	1500	gravel	253	67.57060242/139.8390045
Pangnirtung	950	gravel	1325	66.1451/65.7122
Paulatuk	1219	gravel	294	69.361099/124.058998
Pearce Point (DEW)	unknown	unknown	N/A	69.80000305/122.666664
Pelly Bay (NWS)	unknown	unknown	N/A	68.43333435/89.5999984
Pelly Crossing	1020	gravel	296	62.837200/136.535004
Pelly Lake	unknown	unknown	N/A	66.06666565/101.0833359
Pine Lake	1000	gravel	N/A	60.10309982/130.9340057
Polaris (Little Cornwallis Island)	unknown	unknown	N/A	75.3833313/96.93333435
Pond Inlet	1300	gravel	1315	72.6903/77.9678
Porcupine	unknown	unknown	N/A	66.31666565/140.1333313

Port Radium	1000	gravel	N/A	66.09999847/117.9333344
Prairie Creek	650 (?)	gravel	N/A	61.564701/124.815002
Purtuniq	unknown	unknown		61.81666565/73.94999695
Puvirnituq	1500?	Gravel	1457	60.0497/77.2865
Qikiqtarjuaq	1260	gravel	473	67.5463/64.0318
Quaqtaq	1190	gravel	315	61.0458/69.6169
Rae Lakes	930	gravel	283	64.116096/117.309998
Rankin Inlet	1800	asphalt	2358	62.81140137/92.11579895
Rea Point	1600	unknown		75.3666687/105.7166672
Repulse Bay	1160	gravel	748	66.5214/86.2247
Resolute Bay	1945	gravel	229	74.7179/94.9698
Ross Point (DEW)	Unknown	unknown	N/A	68.59999847/111.1333313
Ross River	1524	gravel	313	61.970600/132.423004
Rowley Island (NWS)	1100 (1076)	gravel	N/A	74.716904/94.969398
Russell Lake	Unknown	unknown	N/A	62.84999847/116
Sach's harbour	1345	gravel	119	71.9939/125.243
Salluit	1190	gravel	1241	62.1816/75.6664
Sarcpa Lake	700?	Gravel	N/A	68.55000305/83.33333588
Sawmill Bay	1500	gravel	N/A	65.73332977/118.9166641
Shepherd Bay (NWS)	1416	gravel	N/A	68.7949/93.4193
Shingle Point (NWS)	1160?	Gravel	N/A	68.928/137.232
Silver City	1040	gravel	Historic mining town, no perm. Pop.	61.028900/138.408005
Simpson Lake (NWS)	1100	gravel	N/A	68.5893/91.9485
Snag	1600	gravel	N/A	62.36666489/140.3999939
Snap Lake	900	gravel	N/A	63.59360123/110.9059982
Snare River	1190	gravel	N/A	63.433300/116.182999
Squanga Lake	2000	gravel	N/A	60.48333359/133.4499969
Stewart Lake	1000	gravel	N/A	64.33333588/125.383331
Stokes Point (NWS)	unknown	unknown	N/A	69.33333588/138.75
Sturt Point (NWS)	1000	gravel	N –A	68.9632/103.76
Taloyoak	1300	gravel	809	69.546700/93.576698
Taltheilei Narrows	1680	gravel	N/A	62.598099/ 111.542999
Taltson River	1200	gravel	N/A	60.38330078/111.3499985
Tanguary Fiord	1128	gravel	N/A	81.409401/76.881699
Teslin	1500	gravel	141	60.17279816/132.7429962
Thunder River	unknown	unknown	N/A	67.46666718/130.8500061
Tintina (Conwest)	1000	Gravel/ turf	N/A	61.08333206/131.2166595
Trout Lake	762	gravel	N/A	60.43939972/121.2369995
Tuktoyaktuk	1565	gravel	870	69.433296/133.026001
Tulita	914	gravel		64.90969849/125.572998
Tungsten/Cantung/Fort Smith	900	gravel	339	61.956902/128.203003
Tulita	914	gravel	505	64.909698/125.572998
Tununuk (DEW)	unknown	gravel	N/A	69/134.6666718
Twin Creeks	889	gravel	N/A	62.619400/131.279007
Wekweètì	982	gravel	137	64.190804/114.077003
West Baffin Island	1000	gravel	N/A	68.6166687/73.25

Whale Cove	1219	gravel	353	62.24000168/92.59809875
Whatì	995	gravel	460	63.131699/117.246002
Wiley	762	gravel		66.4910965/136.572998
Whitehorse	632/1219/ 2895	asphalt	20461	60.709599/135.067001
Wrigley	1067	gravel	122	63.209400/123.436996
Yellowknife	1524- 2286	asphalt	18700	62.462799/114.440002
DEW=Defence Early Warning site (obsolete) NWS=North Warning System site N/A= not available (usually 0), or not applicable				

4.13 Communications Constraints

What constraints are associated with transmitting relevant data to southern Operations Centres in a timely fashion?

At the time this document was written there appeared to be no constraint on communications that would significantly impact on how PAL currently carriers out surveillance operations (see Section 4.1). For example as long as communication is restricted to text messages and does not involve transmission of video or still-images, bandwidth requirements will be relatively low. Therefore, real-time (RT) or near-RT transmission of ship positions, or tracks, based on their AIS reports (while within the aircraft's line-of- sight) can easily be forwarded to operations centres at regular intervals, as uncompressed or compressed text messages, very easily. If satellite communications systems are used to exchange such information, sending it in bursts at regular intervals is significantly more cost-effective than having a dedicated line open at all times. Most imagery (e.g. photographs) tends to be recorded during the flight and then transferred to a database (e.g. SIS) after the mission's end, for evidence purposes, if necessary; it does not, under normal circumstances, need to be transmitted while the aircraft is still aloft.

Table 5 lists the communication options[10] typically found on the CP-140 Aurora (before or after upgrade) or PAL aircraft along with approximate bandwidth, possible constraints, and approximate costs (excluding equipment). When known, the table also includes other potential aeronautical solutions for low to medium data rate SATCOM (MDRS) internet data communications.

[10] Note, the content on aeronautical communications options, including Table 5 and all relevant supporting information in Annexes C, D, and E, from this point until the end of the sub-section 7.13, was provided by the Scientific Authority.

Table 5: Some Aeronautical communications options.

Radio System	Medium	Bandwidth	Constraints/Cost
Air Sat 1-Honeywell	Iridium Satellite network	GSM phone Unknown BW if GSM (CSD) – 9.6kb/s GSM (GPRS) – 170kb/s	System is primarily for voice, not data
AN/ARC-234 SATCOM radio (CP-140)	UHF/VHF (30-512 MHz) UHF LOS (225-400 MHz) UHF SATCOM (270-320 MHz)	75b/s-48 kbps in SATCOM mode; <64kbps in LOS mode (to ground stn)	Most UHF SATCOM satellites (e.g. Skynet, UFO, etc.) are geosynchronous (Annex F) so Arctic coverage is problematic. For LOS service, it must be in view & range of a connecting ground stn.(Cost unknown)
AN/ARC-210 VHF/UHF radio (CP-140)	LOS voice	Narrow band	(Cost unknown)
HF 121BD radio (CP-140)	LOS and OTH to ground stn	<19.2 kb/s	(Cost unknown)
AN/ARC-511 VHF-AM radio (CP-140)	LOS voice	Narrow band	(Cost unknown)
Tactical Common Dada Link (TCDL) (CP-140)	LOS (Ku band) to ground stn, up to 200 km range	~10.7 Mb/s	(Cost unknown)
Iridium phone/data (PAL)	Iridium Satellite network (68 satellites in polar orbit)	2.4 kb/s (per chan.) up to 128 kb/s for OpenPort system. (Annex C)	(for cost see Annex C)
INMARSAT Classic Aero	INMARSAT geosynchronous satellite network	600 bps to 10.5kbps (Annex E)	Based on satellites in geosynchronous orbit with poor coverage in High Arctic (Cost unknown)
INMARSAT Swift64	INMARSAT geosynchronous satellite network	Up to 64kbps per channel & up to 256 kbps by bonding 4 channels. (Annex E)	(see above) Cost ~ $8/min [9]
INMARSAT SwiftBroadband	INMARSAT geosynchronous satellite network	Up to 432 kbps (Annex E)	(see above) Cost ~ $5 to $8/MB (see Annex E, and [9])

Radio System	Medium	Bandwidth	Constraints/Cost
QUALCOMM MDSS	Globalstar LEO satellite network (similar to Iridium)	Up to 128 kbps with possible extension to 600kbps.(Annex D)	This is only a demonstration system which may still have gaps near the poles (see Annex D) (Cost unknown)
UFO= UHF Follow-On MDSS=Medium Data-rate SATCOM System LEO= Low Earth Orbit			

It should be noted that the data rates quoted in the previous table are usually only for those rates that apply to data download, not data upload rates which are often lower. This would imply that it might be more economical to be charged for data throughput rather than on a per minute basis.

Global satellite constellations such as Globalstar and Iridium offer worldwide and polar coverage for several data services for data, high speed and wide band, but quality of service will still depend on the global location. For example, Iridium tends not to work as well near the equator, while Globalstar is weak near the poles (see coverage diagram in Annex D). Globalstar also has some problems with full Duplex transmissions that they expected to have rectified sometime in 2010 after upgrades to the satellite network (see note in Annex D). Both companies now have, or expect to have, aviation products that show promise for relatively high speed data communications which might be useful in the arctic. This communications system is sufficient for near real time, real time and video transmission from the aircraft. The only consideration that should be evaluated further is operating cost. Periodic text messaging at intervals from this type of satellite communications system can be cost managed effectively. However, when these systems are switched to real time, cost and operational requirement considerations must be reviewed.

4.14 Crew Retention

What parameters might play a critical role in the ability to attract crews and retain them?

The ability to sustain any surveillance program (Government, DND or private sector based) is predicated on the necessity to retain crews. Although certain levels of attrition will be expected, maintaining a good level of employee retention will contribute to program professionalism, safety and community integration.

There will have to be a reasonable balance between selecting permanent bases of operations in the North and yet having these locations as operationally reasonable and friendly. For example, although it would be easy to retain crews if such an operation were based in Yellowknife, the distance to the primary area of responsibility would add a significant operational and cost inefficiency into the program.

Another consideration would be to engage in crew rotations. For example, a crew could work in the North on a rotational basis. Although this approach might work, past experiences have shown that establishing a permanent presence in the community will contribute to additional public value in the program. Community participation and potential employment opportunities will contribute significantly to the successful integration of the program into the community.

4.15 Local Native Considerations

How would the consideration of local First-Nations communities affect the selection and continuity of operating bases?

With the establishment of a Northern Surveillance operation, due consideration should be given to providing equal opportunity for Canada's Native populations to participate in employment opportunities with the surveillance program. Recognizing their contribution to Canada's presence in the North would be further exemplified though seeking opportunities for Canada's native peoples. These opportunities could be varied from direct employment to other aviation services provision.

Many opportunities exist for employment in a surveillance program including but not limited to:

- Pilots,
- Sensor Operators,
- Maintenance Engineers,
- Avionics Engineers,
- Operations Management and
- Other clerical and support functions.

The recruitment strategy for the program should probably include a reasonable balance between civilians and former military personnel with relevant experience. Although some private civilian companies may engage in the recruitment of military personnel only, the requirement for a detailed training program should not be avoided. The experience gained in military operations is a valuable contribution, but the systems, methods and standards utilized by the civilian operator may not necessarily be the same.

5 Further Considerations

5.1 Program Security

A program engaged in the detection, collection, identification and reporting of maritime traffic that is also engaged in the creation of enforcement presence needs due consideration for program security. Several issues arise in the implementation of a surveillance program of this nature.

Within the Department of National Defence, a natural security culture exists which contributes to the protection of data, operations, personnel and assets for all operational scenarios, regardless of whether they are domestic or international.

However, this may not be true for Other Government Departments (OGD). It is known that OGD’s today are struggling to identify and classify security threats and in particular the requirement for security information systems.

The main elements of security and protection that should be considered for a private sector surveillance program include, but may not be limited to:

- Facilities,
- Assets,
- Personnel, and
- Data.

For example, the current DFO Air Surveillance program has a contractual requirement for a Transport Canada equivalent to an Enhanced Reliability check for the air surveillance crew. This is basically the equivalent of a TC issued ramp pass. Recognizing the evolving role of the DFO program, the Department recently completed a security threat assessment and the two major conclusions were the following:

- All data collected by, and all data and information related to, the surveillance program will become Protected B; and
- All personnel required to participate in surveillance missions, or to have knowledge of surveillance operations, or to have access to any of the data related to the program must be cleared to the security level of SECRET.

Although this effort is ongoing, it is an important consideration for this study to document as the potential implementation of a surveillance program in the North will require this type of security for the facilities, assets, personnel and data.

The civilian, private sector requirements for security clearance are managed by the Canadian and International Industrial Security Directorate (CIISD) of Public Works and Government Services Canada (PWGSC) and can be found on the internet [10].

For a private sector company to participate in the CIISD security program, they must first be sponsored by a Government agency that usually is engaged, or is about to be engaged, in a relationship that has a security requirement. A typical security implementation program will usually require a period of approximately 12 months to complete.

5.2 Operator Training

The implementation of a private sector program will need to ensure that an effective operator training program is present. Such programs cannot be implemented without existing processes and procedures to ensure effective and efficient operations. (Pilot training, survival training, etc)

5.3 Contractor Performance

A method for measuring and evaluating contractor performance and quality should also be considered in this type of relationship.

Although there are many methods for measuring performance, a recommended feature of a private sector program should be the inclusion of a Government Representative (GR) to participate in the surveillance missions; the alternative would be to have no GR onboard the aircraft. Having a GR available provides a first hand client perspective of mission performance for each and every mission. It is recommended that the GR act in the role of Mission Commander.

Additional measures of contractor performance concern the collection and reporting of the following:

- ***On-time performance*** (OTP) – the ability of the crew and aircraft to be ready to engage the aircraft engines on scheduled time. OTP is usually effective in measuring "controllable" failures in operational management, such as late delivery of fuel, or other possible human resources related issues.
- ***Dispatch reliability*** (DXR) – the ability of the aircraft to move under its own power with the mission equipment suite serviceable to a point where it is capable of completing the mission task. DXR is effective in measuring mission equipment or aircraft mechanical failures that are normally discovered during aircraft start-up.
- ***Mission reliability*** (MXR) – the ability of the aircraft and crew to reasonably complete the tasked mission once the aircraft has commenced the flight. MXR is effective in measuring the ability of the mission equipment and aircraft to reliably complete a mission task.

A trade-off will occur in OTP/DXR/MXR versus cost depending upon the levels chosen. In other words, as the requirement for a higher OTP/DXR/MXR rises, so will the investment in spare components. As a result, it is important to recognize that an evaluation should be performed on the requirement for mission readiness. For example, a reactionary force would likely require a very high level of mission readiness at all times, whereas a general surveillance program will only occasionally require this. A balance between these requirements has to be identified and chosen.

For example, it is suggested that for a program with an operational requirement of 2,000 h per annum, but with a 99% DXR requirement, a minimum of two aircraft would be required to meet the requirement. However, if the requirement was approximately 90%, a single aircraft with sufficient spares for the mission equipment and related aircraft systems could suffice, depending upon operational requirements.

Depending on the contractor's risk tolerance, the performance model strategy may be completed in such a way that it results in one of two alternative scenarios:

- The contractor over invests in spares, thus resulting in more cost to the Crown, or
- The contractor under-invests in spares, resulting in significant contract failure risk.

One potential procurement strategy would be for the contractor to propose a financially based performance. The bid evaluation team would then be responsible to determine if the model proposed reflects the contractors understanding of the potential financial risks associated with such a relationship.

5.4 Procurement Strategy

If a private sector program for Northern surveillance operations were to become a reality, consideration would have to be given to a procurement strategy. Canada has a rich and divers aviation industry that has participated in several degrees of aviation services to the Government. It cannot be understated that surveillance program procurement is not the same as a general aviation contract. The costs and financial risks associated with surveillance operations can either be very successful, or result in a private company ceasing operations. A keen understanding of operations and mission equipment systems must be demonstrated by the potential candidates.

For example, the accurate private sector evaluation of how many travelling wave tubes (TWT's) are required for the airborne X-band search radar is paramount. An underestimate in this component, which is nominally a 9-month lead item, can result in significant periods of downtime (i.e. months) if a contractor does not properly assess the requirement for spares. Such an underestimate leading to protracted down-time could result in significant financial hardship for the contractor. On the other hand, if the contractor overestimates the sparing requirement it could easily result in significant cost inefficiency to the Crown. At a nominal cost of roughly $300,000 per TWT (depending on the radar) purchasing more spares than is really necessary could tie up significant amounts of capital investment.

In essence, when considering a procurement strategy for a surveillance program, there are basic fundamentals and givens such as the mission equipment suite, however, a contracting process must be constructed to ensure that the Crown is engaging in a relationship that has exercised due diligence to ensure that the private contractor does not fail operationally or financially.

5.5 Data Compatibility

It would be considered an imperative that data collected through this type of program be compatible with the information systems used by DND and the MSOC.

5.6 Interoperability

Some consideration should be given to the requirement for the asset to be interoperable with other DND and GOC assets.

The establishment of interoperability can be defined in many ways but is used in this context as a suggestion of the ability of the aircraft to provide tactical information to other Government assets such as DND aircraft and ships using standard military formats and data-links such as Link 11, 16 and 22. This is a sophisticated requirement, but has significant implications for ensuring a program that delivers usable data to the Departments that need it on a timely basis.

An alternative to direct interoperability would be the capability of the aircraft to communicate in near real time to the coastal Joint Intelligence Operation Centres (Trinity and Athena) and then rely on these centres to fuse and disseminate the information. This is currently how the DFO Air Surveillance Program executes the communication of near real time data and is a cost-, and operationally-effective medium.

In order to facilitate more efficient operations and avoid duplication of labour, it might also be useful to integrate or coordinate efforts with several other Government agencies that have varying levels of maritime surveillance capability. These include:

- **1st Canadian Ranger Patrol Group (1 CRPG)** – Joint Task Force North (JTFN), located in Yellowknife, Northwest Territories (NWT) is home to 1st Canadian Ranger Patrol Group. 1 CRPG consists of about 1500 rangers with 56 patrols plus more than 1500 Junior Rangers, all located in 35 communities throughout Nunavut, Yukon, NWT, and Northern British Colombia.. Most reconnaissance performed by 1 CRPG is ground based; however, it is supported, in the air, by four CC-138 Twin Otter aircraft from 440 (Transport) Squadron which is also headquartered in Yellowknife. The Squadron's primary duties include airlift, utility and liaison flights in support of JTFN, the Canadian Rangers, other Canadian Forces activities, as well as the Cadets in the North. The Squadron also provides secondary (limited) surveillance and SaR functions, which are performed visually.
- **Environment Canada (EC):**
  - **Canadian Ice Service (CIS)** – CIS manages the operation of one dedicated reconnaissance aircraft (a Dash 7 owned by Transport Canada and known as CAN-ICE3) that transmits ice charts of actual conditions observed during the flight to ground facilities and vessels. The Dash 7 is specially equipped with radar remote sensing systems and performs missions in the Gulf of St. Lawrence, East Newfoundland Waters, the Great Lakes and the Canadian Arctic. Although the missions are for strategic, tactical and climatological uses, most flights are tactical in nature to support detailed routing of Coast Guard icebreakers and merchant ships. More information on this program can be found at their website [11]
  - **Emergencies Science and Technology Section** (ESTS) – ESTS runs an R&D program on topics related to environmental emergencies caused by spilled hazardous materials. Research topics include:
    - i) Properties, behaviour, detection, measurement, and effects of spilled hazardous materials;
    - ii) Modelling and remote sensing of spilled hazardous materials;
    - iii) Spill countermeasures: evaluation, effectiveness, effects, and environmental benefits of mechanical and chemical treating agents; and
    - iv) Shoreline impact and restoration: development of the Shoreline Cleanup Assessment Technique (SCAT).

  The Section owns and operates two aircraft, a DC-3 and a Convair 580, which are equipped with leading-edge remote sensing equipment, including a laser fluorosensor for oil spill detection. More information on this program can be found on their website [12].

- **Transport Canada (TC) –** TC owns and operates five surveillance aircraft operating under the National Aerial Surveillance Program (NASP). The NASP aerial surveillance fleet, used for marine spill protection, currently consists of three modernized aircraft that are strategically placed across the Country in Moncton, NB (one Dash-8), and Vancouver, BC (one Dash-8) as well as one Dash-7 that splits its time between Ottawa and Iqaluit during the arctic shipping season. These aircraft are the primary means of monitoring shipping activities and detecting illegal discharges in all waters under Canadian jurisdiction. TC also collaborates closely with OGD such as EC under the Marine Aerial Reconnaissance Team (MART) program as well as the Integrated Satellite Tracking of Pollution (I-STOP) program which is a collaboration of Canadian Space Agency, TC, the DFO/CCG (including PAL flights), and EC. More information can be found at the TC website [13].
- **Department of National Defence** – Operates a fleet of 18 Aurora and 3 Arcturus maritime surveillance aircraft for various domestic and international missions.
- **National Search and Rescue Program (NSARP)** – The NSARP is managed and coordinated through the National Search and Rescue Secretariat (NSS) which is an arm's-length organization within the Department of National Defence. The federal departments responsible for delivering the SaR capability in Canada consist of the following:
    - i) Canadian Forces (Department of National Defence);
    - ii) Canadian Coast Guard (Department of Fisheries and Oceans);
    - iii) Royal Canadian Mounted Police (Public Safety Canada);
    - iv) Transport Canada;
    - v) Meteorological Service of Canada (Environment Canada); and
    - vi) Parks Canada (Agency).

  Most marine SaR is provided by the Canadian Coast Guard (CCG) with support from DND. According to a 2009-2010 annual report for the CCG, it has a fleet of 22 helicopters to support its aviation service requirements for (65%) marine security (including SaR), (15%) ice-breaking operations, and (20%) other activities. This fleet, located at eleven bases throughout Canada, is composed mostly (~75%) of Messerschmitt-Boeldow-Bohm BO-105-CBS aircraft, with the remainder being either Bell 212 or Bell 206L helicopters. These aircraft are only suited to visual reconnaissance (i.e. no specialized sensors) and have limited ranges of 400 km, 540 km, and 485 km respectively. The relative payloads of each aircraft are 750 kg, 1500 kg, and 430 kg respectively.

  The CCG SaR helicopter fleet is supplemented by support from DND's dedicated fleet of fourteen CH-149 Cormorants, located at the following bases throughout Canada: 9 Wing Gander, NL; 14 Wing Greenwood, NS; and 14 Wing Comox, BC. The Cormorant has a range of 1018 km, a payload capacity of over 5000 kg and can fly in winds of over 50 knots.

Additional information on some of these government programs and initiatives can be found in [14]

6 UAV Considerations

6.1 Background

According to Section 101.01 of the Canadian Aviation Regulations (CARS) an Unmanned Air Vehicle is a power driven aircraft, other than a model aircraft, that is operated without a flight crew member on board. They are variously known as unmanned aerial/air vehicles (UAV), unmanned aircraft systems (UAS), unmanned vehicle systems (UVS), or remotely piloted vehicles (RPV). The distinction between UAVs and model aircraft is that the latter must not exceed 35kg and be mechanically driven or launched into flight for purely recreational purposes. On the other hand small unmanned aircraft that weigh less than 35kg but are used for non-recreational purposes such as research, policing, or military purposes are designated as UAVs. Of course UAVs can be much larger, depending on their intended use.

The chief advantage of UAVs is that they are not constrained by human limitations or requirements that might put a human flight crew at risk. UAVs are intended to be used in situations that are considered dull, dirty or dangerous; also referred to as the three “Ds”. “Dull” for example would be a situation involving long, tedious and repetitive work often taking six to eight hours (or more) to accomplish such as being given the responsibility of providing detailed surveillance of a large geographic area of regard (AOR), one grid cell at a time. “Dirty” could refer to anything related to nuclear, biological, or chemical contamination that might put a manned aviator at risk. Finally, “Dangerous” is quite self explanatory, involving any activity that might put the crew of a manned aircraft in harm’s way. For example, performing very low flyovers, under the following conditions:

1) flying slowly, or loitering, over, enemy territory where there is a strong possibility of being fired upon; or

2) flying quickly over hilly, unfamiliar terrain which poses a risk of collision with the terrain as well as with birds or other low flying aircraft;

The current UAV market consists of an incredible array of types, manufacturers, and countries of origin. Because of their general utility, it appears that just about any country in the world with a military, scientific or industrial infrastructure has opted into the “game”. As described by the Transport Canada website [15] UAVs have found a use in such activities as: atmospheric research (including weather, and atmospheric gas sampling), scientific research (including geophysical, oceanographic and flight research), mineral exploration, aerial photography (including imaging spectrometry), telecommunications relay platforms, surveillance and reconnaissance (including policing, border patrol, survey and inspection of remote power lines and pipelines, traffic and accident surveillance, emergency and disaster monitoring, weather reconnaissance, fire fighting, and search and rescue), cartography and mapping, agricultural spraying, and advertizing. However, they do not mention such military uses as target acquisition, and/or weapons platforms. According to the “American Institute of Aeronautics and Astronautics (AIAA)” there are more than three dozen countries worldwide that are, or have been, involved in the development or acquisition of UAVs. This organization maintains a website [16] where they present a “Worldwide Roundup” chart of UAV activities. While the chart is based on the information available in April 2003, and therefore a bit dated, it is still quite illustrative of the market complexity. The chart lists 37 countries, almost 100 different companies and over 200 UAV models being developed or produced. This information is also accompanied by a brief general description of each system (e.g. weight, propulsion, size, endurance, payload, mission etc.).

The above preamble is intended to emphasize that an in-depth treatment of UAVs is beyond the scope of this document. However, this section will try to highlight where UAVs might be useful for surveillance and reconnaissance in Canada and with specific emphasis on the Arctic. The discussion is based on the results from some limited studies that tried to address this topic, and some of the recent advances in technology that might make small tactical UAVs a potential option.

6.2 UAV Programs in Canada

While there is a significant interest in, and promotion of UAVs in Canada through such venues as Unmanned Systems Canada[11], two of the better known UAV programs are the Joint Unmanned Surveillance and Target Acquisition System (JUSTAS) program and the Remote Aerial Vehicle for Environmental Monitoring (RAVEN) project. The former is a Canadian Forces initiative while the latter is primarily a civilian project, with some DRDC sponsorship, centred at Memorial University of Newfoundland (MUN) in St. Johns.

The Canadian Forces JUSTAS[12] Project sprang from United States Air Force (USAF) requests for over-flights of Canadian territory by Global Hawk strategic surveillance UAVs in 2002 [17]. Those flights, as planned, never happened; however, the CF proceeded with tests of its own using smaller, leased UAVs. Although the earliest tests mostly involved maritime surveillance trials (e.g. the Pacific Littoral ISR Experiment (PLIX) and the Atlantic Littoral ISR Experiment (ALIX)), recently the JUSTAS program expanded its view to include requirements for deployed battlefield surveillance. The main purpose of this program is to define the CF requirements for UAVs for both domestic and foreign (in-theatre) operations in order to become an informed buyer.

The RAVEN program is, as the acronym implies, a project aimed at developing UAVs for environmental monitoring; specifically to develop payloads to address the operating needs of harsh ocean and arctic environments. The RAVEN I program was to develop [18] "…over-the-horizon data-collection systems for small UAS[13]. These included remotely-operated high-resolution cameras, ship automatic identification system (AIS) receivers, and testing of synthetic aperture radar (SAR)." The project is for collaborative research between Memorial University of Newfoundland (MUN), PAL, the Canadian National Research Council's Institute for Aerospace Research and Institute for Ocean Technology, Carleton University, the University of New Brunswick, and DRDC.

---

[11] A merger of Unmanned Vehicle Systems (UVS) Canada [www.uvscanada.org] and Association for Unmanned Vehicle Systems International (AUVSI) Canada [www.auvsi.org]

[12] Note: JUSTAS project information is based on information prior to 2010. The project is currently on hold.

[13] Unmanned Air Systems

6.3 Manned vs. Unmanned Surveillance of the Arctic

With regard to the "Three Ds" (i.e. Dull, Dirty, and/or Dangerous) in the context of Arctic surveillance, the question arises: "which of these scenarios are likely to occur while performing surveillance and reconnaissance in the Arctic?"

In considering the "Dangerous" aspects of manned flights in the Arctic, there are probably only two main sources to consider:

1. Man-made dangers such as being fired upon; or
2. Natural dangers, such as adverse weather, and rugged terrain.

For the vast majority of cases, as long as the surveillance platform is operating in Canadian air space, there is very little likelihood of being shot at effectively from the surface by small arms or other light weaponry. Other, more advanced weaponry, such as man-portable air defence systems (MANPADS) like tactical surface-to-air-missiles (SAMs) usually have a range of less than 5 km, whereas larger ground based systems would be difficult to transport or hide in the Arctic. For maritime surveillance, the terrain would generally not be a problem unless a manned aircraft flew off course in foggy weather and was flying so low that it flew into mountainous terrain. However, with GPS and inertial guidance systems, this is not very likely. If information was available beforehand that the weather was not going to be safe to initiate a manned flight for a SaR mission, a large High Altitude (i.e. over 9 km) Long Endurance (a.k.a. HALE) or a Medium Altitude (i.e. 3 km – 9 km) Long Endurance (a.k.a. MALE) UAV might be a viable alternative. However, if the adverse conditions are due to high winds, especially cross winds, such conditions would likely preclude the launch of the UAV from the same site as the manned platform. UAVs are inherently less stable than larger aircraft under such conditions and would need to be launched from a less challenging location. Also, considering the cost of having such an expensive asset just act in a backup supporting role and sitting on the ground most of the time might be very unattractive. It is also unlikely that a manned aircraft would encounter one of the "Dirty" situations described earlier. This leaves just the first scenario, the "Dull" work of monitoring vast areas over a period of several hours, while maintaining sufficient vigilance to spot a situation that may be out of the ordinary. In this case, there may be an operational efficiency inherent in the use of a UAV if the sensor operators can be rotated in at a higher rate than for a manned platform. Once a manned platform leaves the base, it is constrained to using the personnel that were on board when it launched.

Normally, an effective approach to follow when attempting to formulate a new concept of operations is to first determine the mission requirement(s), and then select appropriate technology to accomplish the assignment. For example, if the mission requirement is to create enforcement presence, a large High Altitude (over 9 km) Long Endurance (HALE) UAV like the Global Hawk is probably not a good choice, since the technology does not normally permit it to be operating at lower altitudes where enforcement presence is created. For enforcement to be effective, it should also maintain some visibility in order to provide an immediate deterrent. Aircraft such as the Global Hawk operate at altitudes over 30,000 ft and often at heights exceeding 50,000 ft. At these altitudes, such a platform would be virtually invisible from the ground and would therefore not be an effective platform for this mission requirement. Alternatively, as a persistent "covert" surveillance presence, a HALE UAV may be more operationally-effective.

If the mission requires a surveillance and reconnaissance capability equal, or superior to what would be available on a manned platform such as a PAL aircraft, then the equipment suite would need to be similar and a UAV capable of a relatively large payload would be required. Such payloads could only be accommodated on relatively large platforms such as a HALE UAV (e.g. Global Hawk) or a Medium Altitude (3 km to 9 km) Long Endurance (MALE) UAV like a Predator. As with a manned platform, this might require such technologies as X-band multimode radar for target acquisition and classification, as well as EO/IR imaging systems. Since the same (or similar) technology would be used in a UAV as for a manned platform, the required number of crews for an unmanned platform would probably be similar to a manned platform. This would result in a similar requirement for "pilots", sensor operators, and maintenance crews so that there would rarely be a direct cost efficiency to be derived when comparing larger UAV platforms to manned platforms.

An additional problem that has been encountered by UAV operators in Canadian airspace is the necessity of meeting Transport Canada's requirements to ensure the safety of private and commercial air traffic. The greatest concern is for the latter which tend to fly at or near the same altitude as HALE and MALE platforms. Most long range commercial air traffic (e.g. passenger flights) tends to operate at altitudes of 9 km to 10 km (30000 to 40000 ft).

As stated by Transport Canada, according to Section 602.41 of the CARS, "no person shall operate an unmanned air vehicle in flight except in accordance with a Special Flight Operation Certificate (SFOC). To obtain such a certificate, the applicant must show that the predictability and reliability of the aircraft in the desired environment is acceptable. Ultimately the probability of a UAV colliding with another aircraft must be comparably small to that of a manned aircraft. TC states that although the goal is to normalize UAV operations in civil airspace to support routine operations, Detect, Sense and Avoid (DSA) technology has not yet achieved the necessary capability and may be a significant number of years from achieving this goal

There have been a number of useful and informative studies [19]-[26] regarding the potential benefits of using UAVs either in theatre (e.g. Afghanistan) or domestically to carry out missions. However, very few have examined how well they would or would not work, especially from a cost-effectiveness perspective, for surveillance and reconnaissance in the harsh environment of Canada's High Arctic. Two relatively recent Operational Research studies are of particular interest because they have made some useful first steps at trying to determine how UAVs might benefit the GOC in general, and the CF specifically. The two studies were performed respectively by Chan and Dickinson (2003) [27], and Gauthier and Bourdon (2004) [2].

The study by Chan and Dickinson was a fairly in-depth investigation of the potential benefits and effectiveness of UAVs in general to assist in the successful outcomes of missions based on the 11 force planning scenarios shown in Table 6. The results of their study are also summarized in Table 6. Descriptions of the 11 force planning scenarios (FPS), as they were used in that study to evaluate the potential benefit of UAVs, are reproduced in Annex G. As stated in the study, the capabilities of UAVs were examined with regard to whether they could complement, improve, augment, or even replace current ISR assets within the CF as they would be used within the 11 FPS. Their definitions of these four characteristics were as follows (Note: italics are used here, and elsewhere, to emphasise direct quotations):

- *"Complement – A UAV complements existing forces either if it is added for specific purposes which existing assets cannot fulfill or the UAV and other existing assets cannot perform a function separately but together they can. One would analyze the utility quantitatively by assessing the impact of the new capability on achieving mission success."*
- *"Improve – A UAV improves existing forces when it is used to enhance other assets or qualitatively improve an existing capability to perform tasks. A utility assessment would be based on a quantitative evaluation of the incremental or marginal improvement in the ability to perform the task."*
- *"Augment – A UAV augments existing forces when it is used to supplement other assets or expand an existing capability to perform tasks. The UAV is not essential to the tasks, but could be useful. One would analyze the utility quantitatively by evaluating the cost saving in performing missions."*

- *"Replace – A UAV replaces existing forces in some roles or missions if those assets are no longer required for this purpose. A VAV can perform better or satisfy a capability requirement better than other assets with reduced cost or higher efficiency. One would quantitatively analyze the utility by evaluating relative effectiveness of the (two) options."*

The study also rephrased the above definitions in terms of how a commander might interpret them:

- *"Is the UAV essential to perform his mission? (Complement)"*
- *"Will a "better" result be obtained using the UAV? (Improvement)"*
- *"Can the mission be completed without the UAV? (Augmentation)"*
- *"Would other assets be given up to make way for the UAV? (Replacement)"*

Table 6: Evaluation of UAV effectiveness in the 11 Force Planning Scenarios; H, M, and L represent High, Medium and Low respectively, for either priority—as in the Scenario Priority—or for the utility potential. The colour coded shading of the cells facilitates visual interpretation.

FPS Number	**Scenario**	Scenario Priority	Complement Potential	Improvement Potential	Augmentation Potential	Replacement Potential
1	Search and Rescue	H	H	L	M	
2	Disaster Relief	M	M	L	M	M
3	International Humanitarian Assistance	L			L	
4	Surveillance and Control of Territory	H		M	H	H
5	Protection and Evacuation of Canadians Overseas	L			L	
6	Peace Support Operations	M	L		M	L
7	Aid of Civil Power	L			M	L
8	National Sovereignty and Interest Enforcement	H	L	L	M	M
9	Peace Support Operations	H	M	M	M	M
10	Defence of North America	H	H	M	H	H
11	Collective Defence	H	H	M	H	H

According to the authors, the priority rating of each scenario as shown in the table was not based on Department (i.e. DND) policy, but was intended for illustrative purposes to demonstrate how their methodology could be used to assess the operational utility of UAVs and "allow readers to compare a scenario to the assessed UAV utility at a glance". For more details on how they arrived at the priority rankings, the reader is referred to their original OR study.

While the results described in their report are qualitative, they do indicate where UAVs would be of most benefit within the 11 FPS, as well as demonstrate a useful methodology for performing more comprehensive in-depth studies.

The study [2] in 2004 by Gauthier and Bourdon performs a limited cost-benefit analysis comparing the potential capabilities of a Global Hawk (HALE UAV), and a Predator-B (MALE UAV) with the current CP-140 Aurora. The general specifications for each of these airframes are provided in Table 7 taken from [2]. The report quantifies the relative merits of the three aircraft to accomplish various missions based on vignettes from just four of the 11 Force Planning Scenarios: i.e. FPS 1- Search and Rescue, FPS 4- Surveillance, FPS 8-National Sovereignty, and FPS 10- Defence of North America. The Measures of Performance (MOP) that they evaluated, using a combination of calculation and simulation (using Matlab and Satellite Tool Kit (STK)), were the following:

- **Persistence:** The amount of time an ISR system can continuously monitor a given area of interest (AOI).
- **Response time:** the amount of time needed by the aircraft to arrive on station following a tasking, or the time needed by the aircraft to transit from point A to point B.
- **Coverage:** Refers to the area within which a surveillance platform can provide reports on vessels or other surface contacts. It is the maximum surface area that can be effectively patrolled (or swept) by the aircraft while on station.
- **Revisit rate:** The revisit rate is the frequency at which a platform can visit a certain point when tasked to provide continuous coverage of a patrol area.
- **Number of reports:** When targets are in motion, it is often more appropriate to compare the number of reports, which is defined as the number of targets detected and reported by the aircraft.
- **Report frequency:** The average time between consecutive reports of the same ship.
- **Identification capability:** The ability to classify or identify an object of interest. The main focus was on the resolution capabilities of EO/IR imaging systems according to the National Imagery Interpretability Rating Scale (NIIRS) and the Ground Sample Distance (GSD)
- **Target location accuracy:** A measure of the ability of a sensor system to accurately place a target within a reference system and depends on the following:
    1) The aircraft's ability to accurately determine its own position in space;

2) The precision of the measured range between the aircraft and the target;

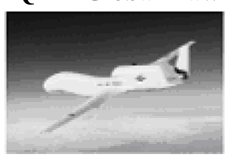
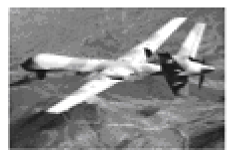
3) The accuracy of the sensor's angular position relative to the aircraft.

- **Weather capability:** The effects of wind, precipitation, icing, and cloudiness/fog on the airframe and the sensor suites.

- **Mishap rate:** The number of aircraft destroyed (or class "A" accidents) per 100,000 h of fleet flight time. This number needed to be extrapolated since none of the UAVs had yet accumulated this amount of flight time.

Also, a statistical model of the operational cost of each of the three aircraft was developed to estimate and compare their relative cost during an extended 14 day surveillance mission. The cost analysis is summarized in Figure 21.

Table 7: Airframe specifications for the Global Hawk, Predator B, and the CP-140 Aurora.

Characteristics	**Northrop Grumman RQ-4A Global Hawk** 	**General Atomics Predator B** 	**Lockheed CP-140 Aurora** 
Altitude Data			
Altitude			
Max (ft)	65000 ASL	52000 ASL	34000 ASL
Loiter (ft)	50000-65000 ASL	40000-52000 ASL	2000-34000 ASL
Endurance (h)	36	48	12.3
Mission radius (nmi)	6000	3500	2000
Max range (nmi)	12000	7000	4000
Speed			
Max (KTAS)	375	225	405
Cruise (KTAS)	343	220	240
Loiter (KTAS)	343	150	206
Max climb rate (ft/min)	3400	2400	1900
Physical Data			
Weight			
Empty (kg)	4200	1800	27900
Fuel (kg)	6600	2700	28400
Payload (kg)	900	300	9000
Max take-off (kg)	11700	4800	64000
Dimensions			
Wingspan (m)	35.4	20.0	30.4
Length (m)	13.5	10.9	35.6
Height (m)	4.6	3.6	10.3
KTAS= knots (kt) air-speed ASL=Above Sea Level nmi= Nautical miles			

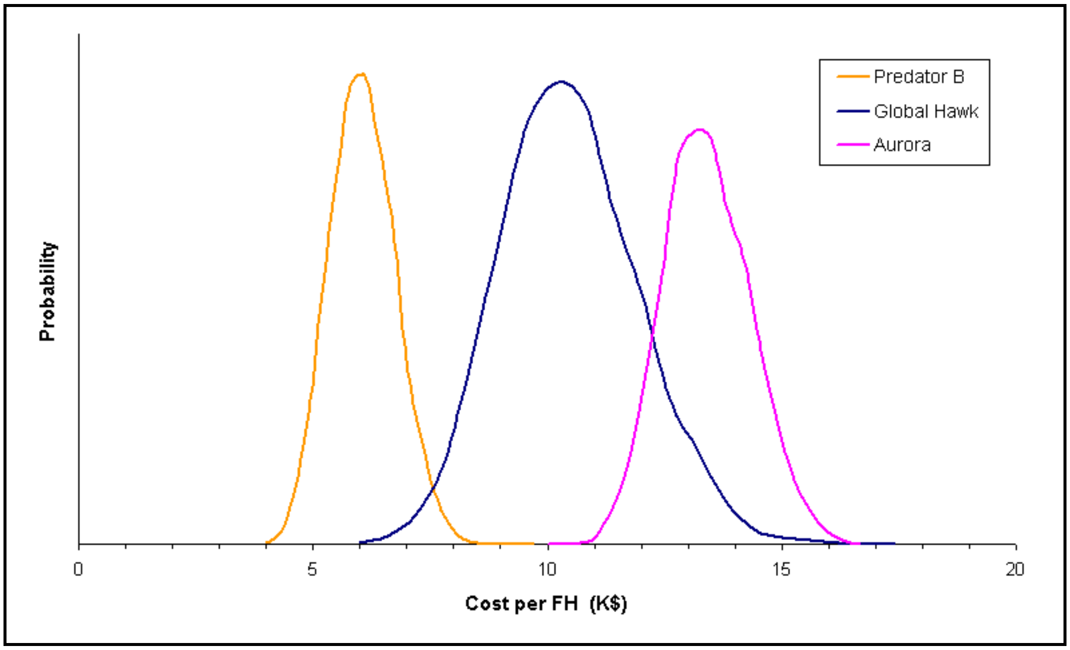


Figure 21: Probability distributions for the total cost per flying hour of each platform in a 14-day continuous surveillance scenario [2].

The comparisons in the report were based on performing the task of continuous (domestic) maritime surface surveillance (west coast) and not the total cost of operations. As a consequence, the results are only a "first order approximation" of the actual cost per flying hour, since the statistical model is limited to cost elements that are directly associated with surveillance missions. A more detailed model would also need to consider the following factors[14] [2]:

a) ***Repair and Betterments:*** Engineering services, repair and overhaul including labour and spare parts by contract as well as betterments over its service life such as the AIMP. The costs of repair and betterments for the Aurora for FY 02/03 were about \$10k/FH. If this is true, then the real cost of operating the Aurora as an MPA in either the MARLANT or MARPAC areas could actually be between \$20k/FH to \$25k/FH.

b) "**Force structure costs:** For M flying hours devoted to maritime patrols, N additional flying hours are necessary for readiness, training, evaluation, and force development. The cost of this overhead was not considered in the costing model. The exact value of N/M depends on the number of aircraft committed to domestic and international operations, and also depends on the CONOPS. For UAVs, this ratio would likely be smaller than the Aurora's, since a larger portion of training could be done in simulators. However, if UAVs were used to reduce commitments of the Aurora fleet, overhead would not necessarily be reduced proportionally. Also, the employment of multiple

[14] Information for items 1) through 4) is from [14] but 1) is paraphrased whereas the others are direct quotes from that report.

fleets (manned and unmanned) to perform similar missions would likely increase logistics and training costs if not optimized."

c) "***Economic factors:*** *The effect of inflation and discounting over the service life of the aircraft were not considered. Fluctuations in the currency exchange rates were also neglected."*

d) *"**Implementation costs:** The various costs involved in implementing UAV squadrons (infrastructure, initial training, etc.) were not included in the model because they are not directly related to the cost of flying the aircraft, but they represent significant one-time investments that will need to be investigated."*

If, for a mission to the Arctic, the above three aircraft must be deployed from either Comox or Greenwood, the time lost in transit must also be considered. For the Aurora, the effective cost may rise by a factor of 1.3 to 2.1 respectively (see Figure 24 and Figure 23). Given the above cost estimates there would at first glance appear to be a cost savings incurred by using a civilian ISR aircraft such as the PAL's King Air 200 compared to the CP-140 Aurora, the Global Hawk, or the Predator B. However the cost/FH difference between the King Air and the Predator B may not outweigh the greater endurance of the Predator B. This assumes that any communications bandwidth issues for the UAV are not an issue, which may be questionable in the High Arctic. If the cost of using a Dash 8 could be kept below the cost of the Predator B, then it would probably have an edge over the UAV due to its greater flexibility, especially if BLOS communications with the UAV were a problem.

The outcome of this study was that for ISR tasks in MARPAC or MARLANT AORs, UAVs and MPAs complement each other in a number of aspects, but UAVs have a significant edge with respect to endurance. Some other important conclusions of considerable significance to Arctic surveillance were:

- *"**MPAs** are all-weather capable, but UAVs are not. UAVs are still vulnerable to strong winds, precipitation, and icing. Climatic conditions historically observed along Canadian coasts would significantly reduce UAV availability and compromise their utilization for time-critical missions."*

- *"**MPAs** also have the capability to fly at very low altitudes and visually identify small surface targets in most weather conditions. The identification capability of UAVs from high or medium altitude would be severely degraded by clouds and fog that are generally present over the MARLANT and MARPAC AORs."*

- *"**MPAs** are multi-purpose platforms capable of switching from surface surveillance, to sub-surface surveillance, to search and rescue, during a single flight. Human presence in the vehicle provides additional flexibility and situational awareness. An onboard crew has a larger field-of-view and is able to make decisions on the basis of incomplete or ambiguous information, adapt to unforeseen conditions, or deal with unexpected situations such as instrument* *malfunctions. No UAV system currently demonstrates this level of versatility and flexibility."*

Although Arctic weather conditions were not discussed explicitly, the above conclusions are very significant since there are extended periods when all of the adverse conditions mentioned above are encountered there.

Given the potential problems associated with using HALE and MALE UAVs for maritime surveillance and reconnaissance in the Arctic, as well as the apparent lack of information regarding their capabilities in that environment, the prospect of achieving cost savings by using unmanned vs. manned platforms may be in doubt. This raises the question about whether smaller, less expensive tactical UAVs might provide a useful supporting role to manned surveillances assets.

6.4 Small Tactical UAVs to Support Arctic Surveillance and Reconnaissance

Recent advances in miniaturized electronic components, such as transceivers, SAR, EO/IR imaging systems plus computer processors and solid state memory chips, have provided small UAVs with some of the capabilities that used to be available only to larger platforms capable of payloads exceeding 50kg. The payload capacity of some of the larger UAVs exceeds the entire weight of some of the smaller UAVs, including their payload.

The aim of the RAVEN project, mentioned earlier, was to test the capabilities of such systems for ocean environment monitoring, to develop payloads that will operate in harsh ocean and arctic environments, and to investigate concepts of use for over-the-horizon data-collection systems on small UAS platforms. They have tested, and continue to evaluate such systems as AIS receivers, and small synthetic aperture radar systems. For example a micro-SAR system [28] was tested by the RAVEN project during mid-November to mid-December in 2007 and marked the first deployment of a SAR payload aboard an Aerosonde system. The system, which was developed by Brigham Young University in Utah and the University of Colorado, weighed less than 2kg (5lb) with the RF electronics module accounting for 900g (31oz). The radar operated at 5.56 GHz with transmission power of less than 1W and stored its data on board the UAV using dual 1 GB flash memory cards able to support a total of 50 min of recording. The SAR radome was a flat-panel array measuring 127x330mm (5in x 13.2in), and was attached to one of the two tail-booms on the Aerosonde. The flight testing program included assessment of the impact of the radome on the UAV's stability and performance characteristics.

A four year follow-on project known as RAVEN II aims to develop collision avoidance systems (a.k.a. Sense & Avoid technology) for small (< 35kg) unmanned aerial vehicles [29]. The program is funded with $3 Million from the Canadian Government's Atlantic Canada Opportunities Agency (ACOA) and is a collaboration of MUN, PAL, and DRDC, with input from Transport Canada Airworthiness personnel and other UAS sector organizations. The premise of the follow-on project, according to the project's Principal Investigator Dr. Siu O'Young, is based on the belief that "…interest in commercial unmanned aircraft operations will focus on small, long endurance aircraft and it is this size class that represents the greatest challenge for sense and avoid systems due to their limited space and low payload weights." The project will use innovations in [15]S&A technologies to develop an Autonomous Collision Avoidance System (ACAS) for small UAS that will consist of: high-resolution digital EO/IR cameras; transponder integration; and ultra-light-weight radar. The development of such a system will facilitate future improvements to small UAVs to give them the capability of being remotely operated via beyond line-of-sight communications with semi-autonomous control, while also providing surveillance information.

A number of payload sensor and communications suites have been developed and adapted for use on the Aerosonde. For example, a company called Airborne Innovations (of Hood River, Oregon) has developed a package called RaptorEye which can be used as part of a "Satcom Imaging" system. This suite combines a "still" camera (e.g. 2 to 16Mpixel Prosilica, Lumenera, or others) and 2 video cameras with a satcom link (single or dual Iridium, Globalstar or Inmarsat) for command and control plus image/video link. According to their brochure, the system is capable of near real-time low resolution video download at 1 frame per second via Globalstar or 0.25 frames per second for the Iridium link. Using a Globalstar link it is able to download a 2 Mega-pixel (Mpixel) image every 20 seconds. This system was used in 2005 to demonstrate over-the-horizon surveillance of the Torres Strait to the Australian Coastwatch program. Airborne Innovations also have a suite that uses an internal 2.4 GHz, 1 Watt, 30+ megabit radio link to provide a very compact lightweight solution for high bandwidth imagery transmission with command and control. These systems use a state of the art processor (Core-2 duo) combined with an on-board image storage capability of over 64 GB. Long range LOS communications can be achieved by combining this system with ground station using a high gain steerable antenna.

If UAVs are needed as either a persistent surveillance asset, or as a cued adjunct to an existing (e.g. ground or space based) sensor system, then perhaps mini UAVs may suffice, if the capability requirements are not set too high. Small UAVs such as the Aerosonde, ScanEagle and the Integrator (a new variant of the ScanEagle) have an operational ceiling of 6.1 km and an endurance of up to 24 h or more depending on the payload and fuel; this puts them in the small MALE category. Early tests with the Aerosonde (Mk 1) and the ScanEagle have shown their endurance by flying across the Atlantic from the UK to Newfoundland [30]. On 20-21 Aug. 1998 the Aerosonde Mk I flew 3270 km in 26 h 45 min and in and in the same year the ScanEagle flew approximately 3000 km from Newfoundland to Scotland. Despite the relatively small payload capacity for such small UAVs, recent advances in sensor technology have made them capable of carrying a full range of sensors, including EO/IR imaging, Synthetic Aperture Radar (SAR) and AIS receivers (see Annex F). For example, the Boeing/Insitu ScanEagle has a payload plus fuel capacity of 6 kg and is capable of carrying a combination, but not all, of the above sensors due to payload size and weight restrictions (the miniature SAR called NanoSAR shown in Annex F developed by imSAR weighs only 900 g and costs less than $100k US [31][48]). On the other hand, a new variant of the ScanEagle called the Integrator is capable of carrying an imaging camera (EO or IR) a SAR, and an AIS receiver. Both platforms also carry a radio system capable of controlling the UAV and downloading imagery and other data at a range of over 100 km. In addition, both the ScanEagle and the Integrator are capable of being launched and recovered from either a land based site (without a runway) or a sea based platform (see Annex F). These types of systems could be used as cued sensor platforms to obtain additional ship identification information when the vessels pass within range of other sensors (e.g. chokepoint sensors along the NWP) which cannot provide sufficient identification for prosecution, if necessary. For

[15] Sense and Avoid (S&A)

example, consider the case of a chokepoint sensor suite placed at Gascoyne Inlet or Cape Liddon overlooking the Barrow Strait as shown in Figure 22. The circle to the left of the figure (shaded red) represents the LOS communications range of the UAV and the area shaded orange represents the land based sensor coverage area. If the land based sensor system detected a ship passing though its area of regard (AOR), a UAV such as the ScanEagle or Integrator could be launched from Resolute and used to take pictures or video for identification as long as the ship was still in communications range..

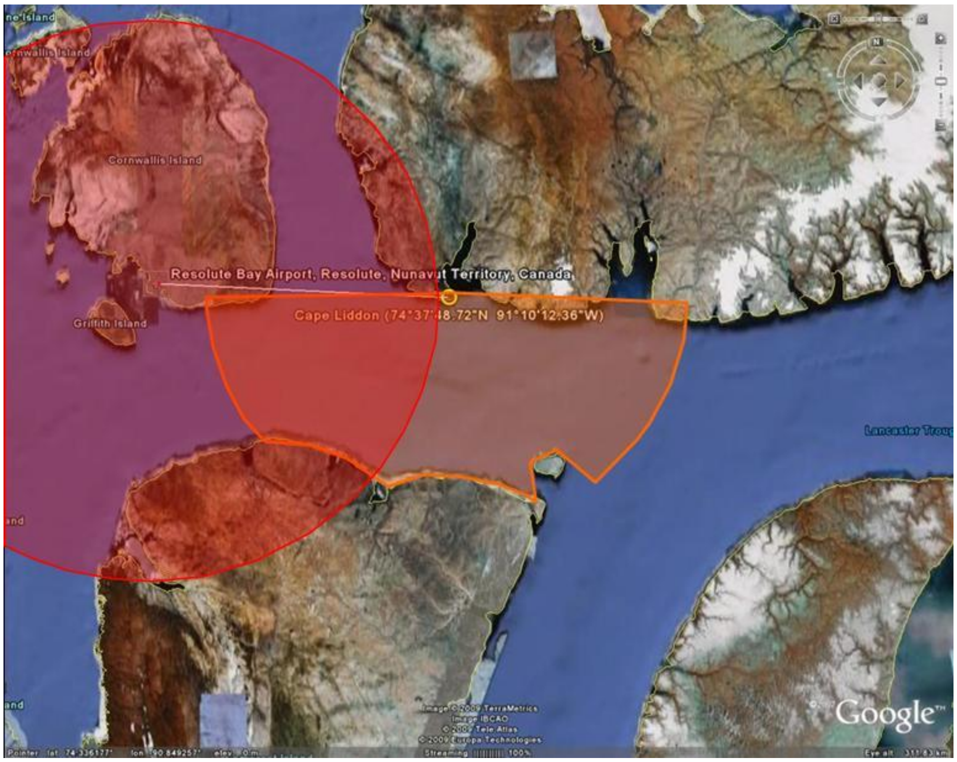


Figure 22: The estimated coverage zone (shaded orange) for a 25 kW marine navigation radar situated on top of Cape Liddon at 320m above sea level compared to the nominal communications range (shaded red) for a ScanEagle or Integrator UAV with a base station at Resolute. The radar coverage is based on a marine target with a Radar Cross Section (RCS) of about 75 dBsm[16].

However, one thing that must be kept in mind is that small SAR systems such as the NanoSAR are only capable of short range operation due to the low power available from the platform. According to the NanoSAR specs, it consumes only 15 Watts and only has a nominal range of 1 km, but it has a resolution of 1 m.

The lowest altitude that either the ScanEagle or Integrator can fly and still remain within LOS communication of Resolute, at a range of just over 100 km, is about 750 m. As long as the imaging systems are capable of obtaining (zoomed?) pictures of a ship at that altitude, that have sufficient quality and resolution for use in prosecution, then these UAVs could perform a useful enforcement support.

[16] dBsm (decibels relative to a 1 square metre target) is a standard unit of RCS measurement.

A couple of advantages that such platforms might have over manned aerial surveillance are the lower cost of maintenance for both the air platform and sensor packages and the fact that mini UAVs, because of their significantly smaller size, require much less fuel to operate. Also the cost of replacing an entire platform and sensors is significantly less than for a manned surveillance aircraft.

Although, these systems have the potential endurance and sensor packages to provide useful surveillance and reconnaissance roles to support enforcement, there may still be some unresolved issues that need to be addressed. For example, due to their smaller size, they are inherently less stable against wind buffeting than larger UAVs and manned aircraft. This could translate into unacceptable image quality. Also, these smaller platforms often do not have as the necessary engine thrust to overcome significant headwinds. Figure 37 shows some typical surface wind data collected by Environment Canada at Resolute on an hourly basis during all of the 2006 calendar year. These are typical of what might be expected in the Arctic, and the UAV must be capable of successfully operating in such an environment. If, in addition to maritime surveillance during the shipping season, the platforms are to be used for land surveillance during the winter months, they must also be capable of operating in temperatures down to -50°C.

In conclusion, although UAVs may present a high technology approach to surveillance operations, it remains to be seen whether they can provide a cost-, and operationally-, effective replacement to manned platforms which provide an overt “physical” presence. However, as discussed, there may be certain mission profiles that could prove to be beneficial. UAVs have not yet been proven as viable replacements to manned platforms in the Arctic, but that may just be a matter of time.

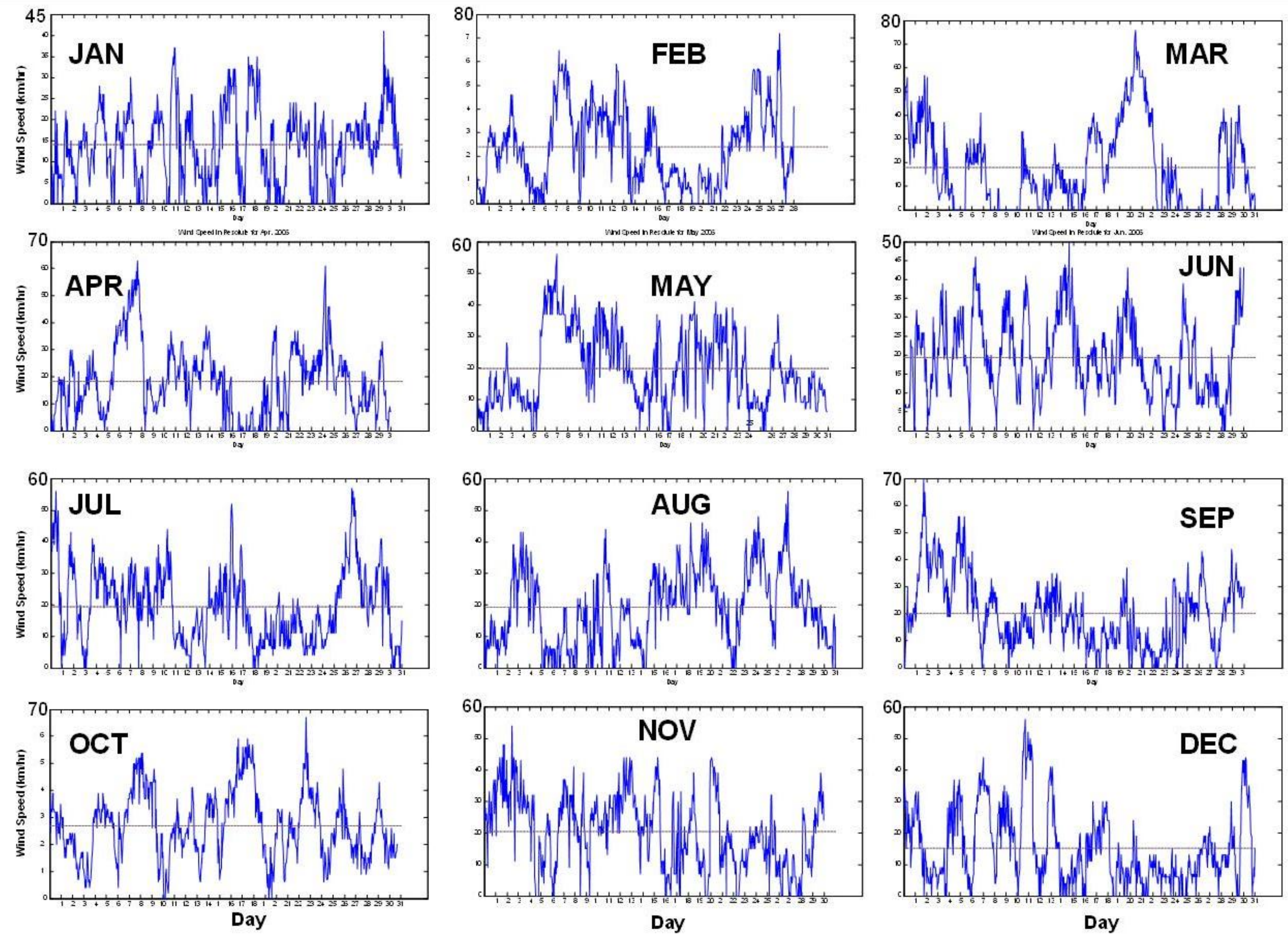


Figure 23: Hourly surface wind speeds at Resolute for all of 2006 [data courtesy of Environment Canada]. Based on the upper limit of the wind speed indicated on the y-axis of each plot, it can be seen that the maximum wind speed seldom exceeded 80 kph and for the month of Aug. averaged to about 30 kph (dashed horizontal line).

7 Conclusions

The purpose of the study is to estimate the feasibility, logistics and costs of providing surveillance and reconnaissance capabilities in the Arctic using private commercial sources. This capability is primarily geared toward maritime ISR activities using small commercial aircraft such as (but not limited to) the King Air, or Dash 7/8, but land surveillance, and the potential use of Unmanned Air Vehicles (UAVs) may also be considered and included.

This report described some of the history behind PAL's current surveillance activities, both at home and abroad, giving testimony to their experience, expertise, and competence at providing such services. It also described some of their current concepts of operation (CONOPS) for enforcement and SR supporting the GOC, and how these CONOPS could be extrapolated to the North. The report also highlights the importance of understanding the roles that a civilian surveillance service provider can and cannot play regarding enforcement, security and defence as well as potential pitfalls associated with trading enforcement capabilities for purely SR capabilities.

This study does not consider the use of civilian commercial aircraft to carry out interdiction activities, since these actions and the specialized infrastructure necessary to perform them are the responsibility of police and military authorities. However, by engaging the private sector to provide SR, military assets will be able to concentrate operations on military issues.

Based on the experience of PAL operations, in order to obtain the coverage and revisit rates required for arctic surveillance, it is recommended that two manned aircraft stationed at Goose Bay or Iqaluit in the East at and at Inuvik in the West would provide between 3000 and 4000 h of surveillance per year and costing about $5000 per hour. Each aircraft would fly a mission about 8 h long every 1.5 to 2 days. This would probably allow the aircraft to monitor most, if not all, of the approaches to the Arctic Archipelago, as well as its internal waterways, on a more regular basis than by current sovereignty exercises. Although it wouldn't provide the same enforcement capability as a CP-140 (e.g. not equipped with magnetic anomaly detectors, sonobuoys or any weapons), it could provide a more persistent presence, at a fraction of the cost of an Aurora. Two new permanent bases would likely require additional infrastructure (hangars etc.) as well as equipment (aircraft maintenance, sensors and associated systems etc.) necessary to the mission. These assets could be provided by the GOC as GFE or by the contractor, but they would then be managed by the contractor

If surveillance and reconnaissance are the only considerations, and not an overt expression of presence, then with the appropriate concepts of operation, a small Remotely Piloted Vehicle (RPV, or UAV) might suffice. Such platforms as the Aerosonde, ScanEagle, Integrator or similar sized systems, with smaller, less capable sensors (EO/IR cameras, NanoSAR, AIS, etc) might meet the basic requirements, assuming they can operate effectively in such extreme environments. Although less capable than a fully manned and equipped aircraft, these platforms require a much smaller footprint in terms of fuel requirements, as well as maintenance and operating crews, with a consequential reduction in cost. However, despite the impressive number of successful mission hours logged by such systems as the ScanEagle in the Middle East, they (and their sensors) must still prove themselves in the harsh Arctic if winter use is required.

Based on the evidence provided, the following conclusions can be drawn:

- Capability –PAL has the capability to operate and provide a program for the surveillance of Canada's Arctic that is highly effective from both a cost and operational perspective. The civilian commercial sector has shown that it has significant capability to operate both manned and unmanned surveillance missions.
- Public and Political Education – There is an apparent lack of knowledge regarding the role that civilian commercial airborne surveillance operations can provide to Canada with a cost and operationally-effective program, i.e. that it is possible for some of this work to be carried out by the private sector, and is not solely the responsibility of the military. This could be rectified with the appropriate public awareness campaign.
- Economic benefit – In addition to the significantly lower (per hour) estimated cost of surveillance provided by a civilian commercial airline, such a program would result in a significant economic benefit to the northern communities where they would be based.
- Contracting Term – An ideal contracting term would be about ten years; a shorter term would result in private civilian contracts with higher annual capital and financing costs, causing higher costs to Government; a longer term would result in client risks associated with obsolescence.
- Manned vs. Unmanned Surveillance – It is questionable whether large HALE or MALE UAVs would provide any significant cost or capability advantage over manned surveillance aircraft for Arctic surveillance given the reasons cited earlier. However, smaller long endurance UAVs with smaller less expensive payloads may fill a useful niche as an adjunct to a manned capability or to other stationary land based surveillance sensors. Depending on an appropriate CONOPS, they could be used when manned aircraft are not available due to equipment or pilot down-time, or if aircraft have been deployed elsewhere and cannot respond in a timely fashion. They could also be used in occasional situations where a surveillance presence is essential, but weather or other conditions are deemed unacceptably dangerous for a manned mission.

It would be extremely useful to evaluate concepts of operation for small UAVs, with the size and sensor payloads mentioned earlier. These would be based on a combination of simulation and in-situ experiments in the harsh Arctic environment. Without such trials informed decisions are not possible. Subsequent to this, it would also be extremely useful to perform a more detailed, full cost-benefit analysis to compare the performance of civilian MPA (variants of the King Air, Dash 7/8, etc) as well as both large and small UAVs to the current CP-140 Aurora. Such a study could investigate how the civilian assets could complement the Auroras.

References

[1] Jane's All the Worlds Aircraft 1996-97

[2] Gauthier, Y., Bourdon, S., Performance, Benefits and Costs of Long Endurance UAVs for Domestic Maritime Roles, Directorate of Operational Research (Maritime, Land, & Air)-Operational Research Division, ORD Project Report PR-2004/14 August 2004, 94 pages

[3] Addison, M. , A Comprehensive Aerospace Surveillance System For the Canadian Arctic, Canadian Forces College, JCSP 33, Exercise New Horizons, 23 April 2007, 27 pages

[4] Transport Canada (date modified: 2 Mar. 2010), The Zone/Date System, Transport Canada, http://www.tc.gc.ca/eng/marinesafety/tp-tp12819-zone_date-2888.htm (3 July 2010)

[5] Canadian Coast Guard, Chapter 5: Shipping in the Canadian Arctic, Government of Canada, http://www.ccg-gcc.gc.ca/e0010979, (3 July 2010)

[6] Statistics Canada, (Revision Date: unknown), www.statscan.gc.ca, Government of Canada, 3 July 2010

[7] Copyright 2007-2009, OurAirports, Megginson Technologies Ltd, www.ourairports.com, 25 March 2009

[8] Nav Canada, Canada Flight Supplement- Canada and North Atlantic Terminals and Enroute Data-Effective 0901Z 18 January 2007 to 0901Z 15 March 2007, Copyright 2007 Nav Canada and Natural Resources Canada

[9] Stephen Pope, "Cool Stuff- Cabin Tech '09: These days, you can stay as web-connected in the air as you can in your office", Business Jet Traveller Online, 4 June 2009

[10] Public Works and Government Services Canada, Industrial Security Program, Government of Canada, http://ssi-iss.tpsgc-pwgsc.gc.ca , 10 June 2009

[11] Canadian Coast Guard, CHAPTER 1: Ice Advisory and Shipping Support Services, Government of Canada, http://www.ccg-gcc.gc.ca/e0010722, 3 July 2010

[12] Environment Canada, Government of Canada, www.ec.gc.ca/scitech/default.asp?lang=En&n=66A57AF7-1, 3 July 2010

[13] Transport Canada, Spill Prevention: National Aerial Surveillance Program, Government of Canada, http://www.tc.gc.ca/eng/marinesafety/oep-ers-nasp-2195.htm, 28 Aug. 2011

[14] Brookes, D (Editor), The First Northern Watch Conference and Exposition on Arctic C4ISR 21 October 2007-23 October 2007, Dalhousie University, Halifax, Nova Scotia, Conference Proceedings on CD-Rom, 820 pages, CP-2008-003

[15] Transport Canada, Revision Date: 2010-05-03, Unmanned Air Vehicle (UAV), Government of Canada, www.tc.gc.ca/eng/civilaviation/standards/general-recavi-brochures-uav-2270.htm, 20 July 2010

[16] American Institute of Aeronautics and Astronautics (AIAA) (last update: 23 Nov. 2004), Worldwide UAV Roundup, www.aiaa.org/images/PDF/WilsonChart.pdf (23 Nov. 2004)

[17] CASR, Canadian American Strategic Review-Background JUSTAS: Canadian Forces JUSTAS (HALE/MALE UAV) Project, http://www.casr.ca/bg-uav-justas.htm, 15-Jan-2010

[18] McGroggan, L (Crystal Public Relations, Canada), FEATURE ARTICLE – Raven Project To Develop Small UAS S&A, , University of North Dakota's Center for UAS Research and Education, http://www.uasresearch.org/UserFiles/File/105_Feature-Article_Project-Raven-to-Develop-Small-UAS-S&A.pdf, 15 Jan. 2010

[19] Fox, R. W., UAVs: Holy Grail for Intel, Panacea for RSTA, or Much Ado about Nothing? UAVs for the Operational Commander, Naval War College, Newport RI, 13 Feb. 1998, 34 pages

[20] Thom, M.C., UAVs for the Operational Commander: Beyond Tactical Reconnaissance, Surveillance and Target Acquisition (RSTA), Naval War College, Newport RI, ADA325830, 32 pages.

[21] Van Bavel, G.H., Pacific Littoral ISR Experiment 1 : Evaluation-Quantitative Methods and Measures, DRDC − CORA Technical Report TR 2005-34, December 2005, 160 pages

[22] Van Bavel, G.H., Dooley, P.W., Atlantic Littoral ISR Experiment (ALIX) Evaluation: A Method to Synchronize Contact Report Times from UAV-Borne Sensors, DRDC CORA TM 2006-47, December 2006, 50 pages

[23] Van Bavel, G.H., Dooley, P.W. Atlantic Littoral ISR Experiment (ALIX) Evaluation: IISRA-Induced Impediments to UAV AIS and MPR Data Fusion in Scenario 3A

[24] Wheatley, S., The Time is Right: Developing a UAV Policy for the Canadian Forces, Centre for Military and Strategic Studies, University of Calgary, CDAI-CDFAI 7th Annual Graduate Student Symposium, RMC, October 29-30, 2004, 19 pages

[25] Runge1, H., Rack, W., Ruiz-Leon, A., Hepperle, M., A Solar Powered HALE-UAV for Arctic Research, Preprint from the 1st CEAS European Air and Space Conference, Sept. 2007, Berlin, Copyright DGLR, Bonn, Germany, 6 pages

[26] Dittmann, P. (LCol.), In Defence of Defence: Canadian Arctic Sovereignty and Security, Journal of Military and Strategic Studies, Spring 2009, Vol. 11, Issue 3., 62 pages

[27] Chan, J., Dickinson, R.G., An Examination of the Utility of UAVs Across the Canadian Force Planning Scenarios, Department of National Defence Canada- Operational Research Division, Directorate of Operational Research (Joint), DOR(JOINT) Research Note RN 2003/04, August 2003, 84 pages

[28] La Franchi, P. (Copyright © 2007-2011) , Aerosonde synthetic-aperture radar test flights completed ahead of Canadian ice survey demonstration, Reed Business Information-Flightglobal, http://www.flightglobal.com/news/articles/ izmag de-synthetic-aperture-radar-test-flights-completed-ahead-of-canadian-ice-survey-211473, 12 Jan. 2007

[29] Benchmarks-Winter 2008, On-line Newsletter of the Memorial University Faculty of Engineering & Applied Science

[30] Biass, E.H., Braybrook, R., Hooton, E.R., Keggler, J., Richardson, D. ,et al, "The Growing World of Unmanned Airborne Spies-Complete Guide to Unmanned Air Vehicles", Supplement to Armada International, March 2004

[31] David Schneider, "+- Winners & Losers, 2009 – '+ Winner, Remote Sensing': Radio Eye in the Sky, imSAR's Synthetic-Aperture Radar is Both Small and Affordable", IEEE Spectrum, January 2009

[32] Honeywell Aerospace, Copyright March 2008, Airsat II Satellite Communications—Dependable Worldwide Voice and Data Communications for Commercial Aircraft, Honeywell International Inc., http://www51.honeywell.com/aero/common/documents/myaerospacecatalog-documents/ATR_Brochures-documents/AirSatII_2pg_A4.pdf, 2 pages, 3 July 2010

[33] Delta Wave Communications Inc., Iridium Open Port Hardware pricing; Iridium Open Port Airtime pricing—End User, http://www.deltawavecomm.com/IridiumOpenPort.htm, 3 July 2010

[34] Globalstar Satellite Communication Services, Revision Date: 26 March 2004, Airborne Medium Data-Rate Satcom System, Globalstar, http://common.globalstar.com/docs/mdss.pdf, 8 Jan. 2010

[35] Globalstar, Copyright 2010, News Center—Constellation Update and Advisory, Globalstar Corporate Site, http://www.globalstar.com/en/news, 8 Jan. 2010

[36] Globalstar, Copyright 2009, Airtime Pricing—Data Pricing, Globalstar Canada, http://www.globalstar.ca/en/content.php?cid=202, 2 Feb. 2009

[37] Globalstar, Revision Date: June 2009, Voice and Data Coverage, http://www.globalstar.ca/en/content.php?cid=300, 8 Jan. 2010

[38] Inmarsat, Revision Date: 06/03/2009, http://www.inmarsat.com/Downloads/English/Coverage/Post_Repositioning_coverage_Aero.pdf?language=EN&textonly=False, 8 Jan. 2010

[39] Inmarsat, Revision Date: 06/03/2009, Classic Aero: Classic Services—Aviation Standards, http://www.inmarsat.com/Services/Aeronautical/Classic_Aero/Coverage.aspx?language=EN&textonly=False, 8 Jan. 2010

[40] Inmarsat, Swift 64—ISDN and Packet Data, 15 Sept. 2008, http://www.inmarsat.com/Services/Aeronautical/Swift_64/default.aspx?language=EN&textonly=False, 2 pages, 8 Jan. 2010

[41] Inmarsat, 06/03/2009, Creation Date: 23 Sept 2009, Swift Broadband—High-speed, IP-based voice and data, http://www.inmarsat.com/Services/Aeronautical/SwiftBroadband/default.aspx?language=EN&textonly=False SwiftBroadband_fact_sheet_EN.pdf, 2 pages, 19 Feb. 2011

[42] Ground Control-Global Satellite Internet Solutions, Revision Date: 7 Jan. 2010, BGAN - Broadband Portable Internet & Phone, www.groundcontrol.com/BGAN.htm, 12 Jan. 2010

[43] Holland, G., 20 Jan. 2003, The Aerosonde System, Aerosonde Ltd, http://www.aerosonde.com/downloads/the_aerosonde_system.doc, 4 pages, 25 Sept. 2007

[44] Vu, Ryan, 18 Feb. 2006, A Proven Platform (Aerosonde promotional video), Aerosonde Ltd, http://www.ctie.monash.edu.au/hargrave/AEROSONDE_VIDEO/ProvenPlatform.zip, 25 Sept. 2007

[45] INSITU, 27 Oct. 2009, ScanEagle (fact sheet), INSITU Inc., http://insitu.com/documents/Insitu%20Website/Marketing%20Collateral/ScanEagle%20Folder%20Insert.pdf , 2 pages, 11 Jan 2010

[46] INSITU, 15 Sept 2009, Integrator (fact sheet), INSITU Inc., http://insitu.com/documents/Insitu%20Website/Marketing%20Collateral/Integrator%20Folder%20Insert.pdf , 2 pages, 11 Jan 2010

[47] imSAR, Copyright March 2008, nanoSAR (fact sheet), imSAR LLC, http://web.archive.org/web/20090225123839/http://www.imsar.com/NanoSAR%20Flyer_03_08.pdf, 2 pages, 11 Jan 2010

[48] Hanlon, M. (18 March 2008), ScanEagle UAV gets Synthetic Aperture Radar SAR, Gizmag, PDT, http://www.gizmag.com/scaneagle-uav-gets-synthetic-aperture-radar-sar/9007/, 10 Jan. 2010

[49] Jane's Aircraft Upgrades (JAU, on-line), Copyright © I Global Limited 2009, Bombardier (deHavilland) Dash–8 - Special Mission version IIHS Jane's : Defence & Security Intelligence & Analysis, http://search.janes.com, 14-Sept.-2009

Annex A Provincial Aerospace Limited

A.1 DFO Air Surveillance Program

The concept of civilian commercial aerial surveillance in Canada is not a new one. Perhaps the largest and longest running example of civilian commercial surveillance in Canada is the DFO Air Surveillance Program (ASP) in its relationship with Provincial Aerospace, a private company which is headquartered in St. John's, NL Canada. This private sector company provides DFO with over 7,000 h of airborne surveillance service on an annual basis utilizing four fully mission equipped King Air 200 aircraft.

The program has been competitively tendered and won by Provincial Aerospace four consecutively times since 1990 and the current contract runs until March, 2010. There have been varied levels of competition for the contract since its inception, but when the opportunity was tendered in 2003, there was only one bidder from the private sector; Provincial Aerospace.

Figure 24: The King Air 200, the aircraft type currently in use by the DFO Air Surveillance Program [photo courtesy of Provincial Aerospace Ltd.]

The concept of operations (CONOPS) generally consists of the scheduling of missions by DFO on a weekly basis. The schedules also accommodate emergency 24/7 dispatch of aircraft. The missions include a Government representative, or mission commander, who is responsible for briefing the crew on the mission tasking and particulars of the tasked area. The crews from Provincial Aerospace operate the aircraft and mission equipment at the direction of the mission commander. Data are collected and verified by the mission commander at termination of the flight, and reports are distributed electronically to DFO and other Government Departments as required.

In essence, DFO has total control over where the aircraft fly and when.

An important fact to note here is that the contractual relationship between PAL and the GOC permits the DFO ASP to be used directly by any OGD. In these cases, the OGD will supply the Mission Commander. These missions are also coordinated around the DFO schedule requirements. For example, OGD's utilized the aircraft available under the DFO ASP for a total 676 h in the 2006/2007 fiscal year.

The current aircraft contracted by DFO is the King Air 200 which meets all of the requirements of the DFO ASP. Its major features include:

- Stable, low altitude operations – The aircraft is extremely stable at low altitudes down to 200 ft which is a critical feature contributing to the ability of the aircraft to create enforcement presence
- High altitude operations – When necessary, the aircraft can ascend to altitudes in excess of 27,000 ft which provides for long range target detection and mapping using the airborne radar
- Dash speed – The aircraft has a dash speed of 320mph which permits the aircraft to be within Canada's 200nm EEZ within approximately 1 hour of take-off
- Patrol speed – The aircraft is stable at 150-180kts for a patrol speed which is effective for visual interrogation of targets of interest.
- Engines - Two reliable Pratt & Whitney PT6A-41 engines provide maximum crew safety and comfort when manoeuvring at reduced airspeed at low altitudes
- Cabin space – sufficient for 6 people including all mission equipment and workstations
- Cost-effective – The King Air aircraft is competitively priced on the used aircraft market, and has a high level of reliability and low cost of operations

In essence, the King Air makes for a safe, cost and operationally-effective platform for the DFO ASP mission profile.

The contract calls for a complete turn-key service in which the company retains ownership, maintenance and operation responsibilities of the aircraft. Performance measurement tools are used such as dispatch reliability, on-time performance and mission reliability to ensure that the contractor is providing a consistent, quality, and reliable program to the Department.

The aircraft include a number of systems and capabilities to meet the requirements of the program:

- Airborne radar – The program is currently employing two different radars; the Litton APS-504(V)5 and the ELTA EL/M2022(V)3 radars. The APS-504(V)5 was originally designed for anti-submarine warfare applications and is an effective tool for long range, small target detection which is essential for effective surveillance missions. The recently acquired EL/M2022(V)3 radars are modern, fully multimode search radars which contribute to not only small target detection, but also provide significantly more capabilities for target classification and area mapping though tools such as Inverse Synthetic Aperture Radar (ISAR), Spot SAR and Strip SAR.

- Forward looking infrared – The gyrostabilized FLIR Systems Star Safire II series includes three sensors for imaging; a color CCD wide angle zoom camera, a spotting scope for long range imaging, and an infrared camera for night observation of targets of interest
- Tactical data management – The aircraft are equipped with a proprietary Airborne Data Acquisition and Management (A.D.A.M.) System developed by Provincial Aerospace. The system has the primary responsibilities of data collection, management, controlling digital satellite communications from the aircraft and post mission report generation.
- Navigation – Aircraft are equipped with GPS as the primary source of navigation. The airborne radars also use accurate information from an integrated inertial navigation system (INS) to improve signal processing and small target detection
- Digital photography – For still photography, aircraft are equipped with the Nikon D2x digital camera that also features a link to the onboard navigation system for annotation of date, time, latitude and longitude on imagery.
- Night-time identification – For night-time operations, aircraft are equipped with visible flash systems which permits the aircraft to acquire positive identification (name/number) of targets of interest. Infrared technology is incapable of providing positive identification. Although laser illuminated (and sometimes active range gated) systems are available, they do not provide the level of quality of a visible flash combined with a digital camera. These images have the advantage of being easily submitted and explained in a court of law.
- Communications – All aircraft are equipped with a combination of HF, V/UHF FM and AM radios. Included in the communications suite is also a satellite communications system that uses the Iridium satellite communications system. The throughput is suitable for packet communication only and is not suitable for the transmission of significant files such as video or detailed photography.
- Data communications – The onboard satellite communications system is controlled by the tactical system which uses the link to communicate regular data packages to a ground based server.

A.1.1 Data Communications

Data collected from the program is distributed in near real time and at post mission from the aircraft. Although there are significant upgrades available to the program in the form of high speed digital communications with the aircraft for real time applications, the current contract does not require such bandwidth. Otherwise, data flow is managed primarily in two forms:

- Near real time
- Post mission

For near real time communications, the onboard A.D.A.M. System will periodically (at minimum every 15 minutes) connect to a ground based server that then makes the information available on the Surveillance Information Server (SIS)[17] and also repackages data for automatic e-mail distribution to users such as DND. The following diagram depicts this flow.

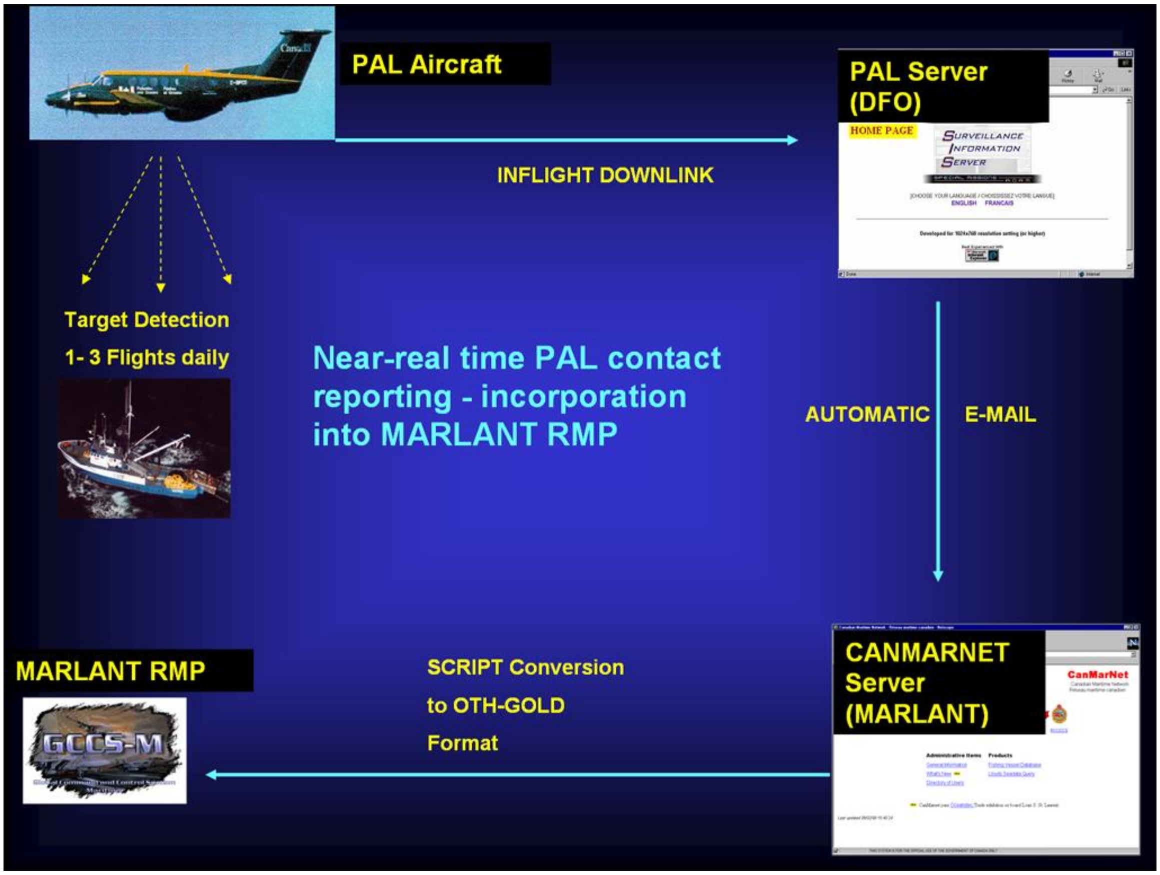


Figure 25: Data flow that depicts the data contribution to MARLANT. This same diagram also represents the distribution of data to Trinity and Athena [Figure courtesy of Provincial Aerospace Ltd.]

It should be mentioned here, that once the data has been received on the Trinity servers that it is automatically available to Athena in Esquimalt, British Columbia.

The following diagram in Figure 26: depicts the full distribution of data from the DFO Air Surveillance Program:

[17] Note: since the first writing of this document, SIS I has been replaced by an updated version called SIS II (see https://www.provincialairlines.com/AMSDSIS.htm)

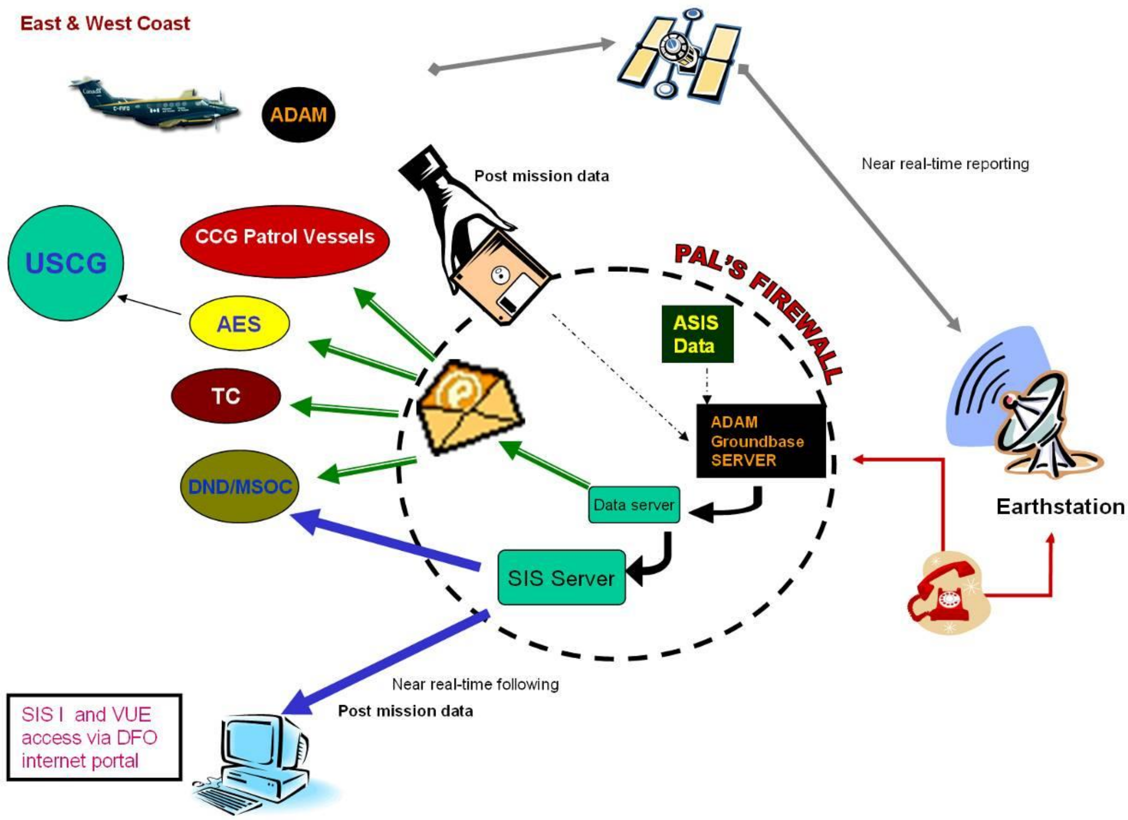


Figure 26: Data distribution concept for the DFO Air Surveillance Program. [Figure courtesy of Provincial Aerospace Ltd.]

A.1.2 Program Utilization

As the following chart in Figure 27: illustrates, the program has increased steadily in utilization since the 2001 timeframe.

The aircraft utilization has increased primarily and directly through DFO, although in recent years OGD use has increased slightly for direct use of the assets. The most important fact to note is that there has been a significant increase in the use of the data collected from the program.

In the 01-02 timeframe, additional funding was provided to the program in recognition of the additional capacity for flying hours and the cost-effectiveness of acquisition. DFO increased their average annual utilization from approximately 4,000 h/yr to 5,500 h/yr. The additional hours resulted in additional enforcement presence which also translated into additional data for not only DFO but also other government departments. In the fiscal year 04-05 an amendment was executed to the contract that permitted it to be expanded to include an additional dedicated aircraft to the west coast of Canada in Comox.

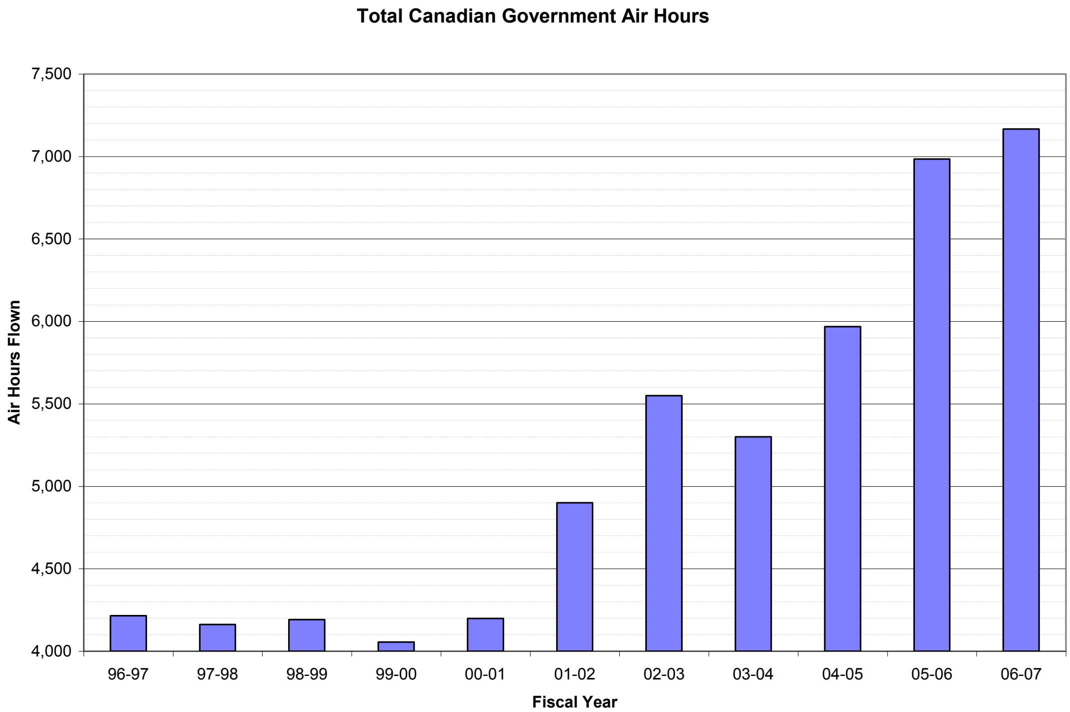


Figure 27: DFO ASP hours of service [figure courtesy of Provincial Aerospace Ltd.].

As a result, there has been a consistent increase in the air hours to the program since the 01-02 timeframe. However, 05-06 and 06-07 fiscal years, the trend is levelling off.

A.1.3 Program History

The history of the Department of Fisheries and Oceans air surveillance requirements stretches back a number of decades but has its origins in the form of operational relationships with the Department of National Defence. Traditionally, DND has provided regular air surveillance support to DFO for the primary purposes of enforcement presence and general data collection requirements.

During this period, a private sector company by the name Atlantic Airways had engaged in contractual relationships with the east coast oil exploration industry. These contracts required the private company to execute visual reconnaissance flights over the Grand Banks. The flights comprised of pilots and ice observers, who would visually detect, and then record on manual maps and reports, the locations of ice formations. This information was then reported to the oil companies operating in the ice infested waters off the east coast of Newfoundland.

With the tragic sinking of the Ocean Ranger in 1982, and a subsequent Brander Smith report that followed, a key recommendation was made for the industry to vastly improve the methods in which the ice reconnaissance missions were being executed. Icebergs were deemed by the industry to be a significant threat to safety of operations at sea. As a result, the detection and accurate localization and drift prediction of icebergs was recognized in the report as an important issue that should be resolved.

Figure 28: Provincial Aerospace commenced surveillance operations with the east coast oil exploration and production industry, making it the first private operator of anti-submarine warfare technology in the World [photo courtesy of Provincial Aerospace Ltd.].

In 1985, Atlantic Airways responded to this requirement by researching technologies that would overcome the challenge of detecting icebergs in the extreme environment of the North Atlantic. Icebergs presented a technical problem in that, although sometimes very large, the radar cross section (RCS) of the formations changes with every position of the aircraft. With every position of the aircraft as it is moving, the fact and reflective properties of the formation also change because no single side or angle is precisely the same. Depending upon the type of iceberg, detection can prove to be very challenging.

No general commercially available technologies existed at the time to perform the daunting task of detecting icebergs effectively at distance. Hence, Atlantic Airways began to explore technologies that had been designed for use in the military world, and hence immediately discovered a potential solution: anti-submarine warfare radar.

This technology was designed for the detection of submarine snorkels at a distance of up to 50 nmi from an aircraft. At the time, however, the general availability of systems that would be cost-effective for a private sector company anywhere in the world was almost non-existent, except for one: the Litton Systems Canada Limited APS-504(V)5.

Litton Systems had engaged in creating a new generation of the '(V)5 but with the target market. This resulted in the sale and operational implementation of Litton's first APS-504(V)5 being brought into operation, not in an anti-submarine warfare role, but in a commercial iceberg detection role.

The key point that has to be stressed and highlighted in this successful implementation of the APS-504(V)5 into private sector ice reconnaissance operations was the reality that this event marked the beginning of an era in which surveillance technologies originally design for military application would now have cost and operationally-effective applications in the private sector world. In fact, Atlantic Airways is the first private sector company in the World to operate digital X-band anti-submarine warfare technology. This marked the beginning of a ground breaking opportunity for the private sector in Canada.

The operation required advanced military technology, but clearly did not require a military operation.

Within the same timeframe, the east coast oil exploration industry was in a downswing and the then Atlantic Airways operation approached the Department of Fisheries and Oceans to engage in a trial surveillance operation with the Company. During the same period, the Department of National Defence was engaged in providing DFO with general surveillance capability through the use of aircraft from the Summerside, PEI base utilizing Tracker fleet. DFO would avail of inventory hours available in the fleet to conduct fisheries and sovereignty patrols along the east coast of Canada and occasionally to the Davis Straits.

In 1989, the Government announced the retirement of the Tracker fleet, which left DFO in the position of having to consider contracting out for its surveillance requirements. Through the demonstration programs with Atlantic Airways, it concluded that the private sector in Canada had the capability to provide a turn-key advanced program. Within months, the Department conducted a competitive public tender process. Canadian industry reacted and competed strongly for the program which resulted in the first private sector airborne surveillance program being awarded to Atlantic Airways.

From the period between 1990 and 2000, the DFO Air Surveillance program generally remained financially and operationally fixed. It was during this period that general Government policy was not complimentary to operations of various sorts across a number of Government departments. Furthermore, this was complicated by the fact that general public policy did not recognize or contribute to an environment that considered surveillance of Canada's critical approaches or oceans to be either a security or an enforcement issue.

The entire sense of national security was rewritten after the tragic events of September 11, 2001, in New York City. In the months that followed, several new policies were released with the intent of providing funding to programs that contributed to the security of Canada, and its infrastructure. Notably, however, the nation was publicly criticized (during this period) because of an apparent lack of investment in surveillance of its coastlines. In the Federal Government Budget of December, 2001 and under a section dedicated to marine security, funding was directly identified that would increase the flying levels of the DFO Air Surveillance Program from approximately 3,500 h/yr to almost 5,500 h/yr.

This increase did not go without recognition by another key player in the maritime surveillance business in Canada; the Department of National Defence. Key individuals within the Department and in particular the Naval Intelligence Centres Trinity (East Coast) and Athena (West Coast) recognized the need to integrate existing data sources. One of those sources was the DFO ASP.

Provincial Aerospace was approached by DND, to explore manners in which the Department could receive both in near real time and at post mission, the data collected during flights. Efforts were initiated to provide both Trinity and Athena with near real time and post mission information from the surveillance missions.

This data source now constitutes a significant contribution to the daily construction of the Recognized Maritime Picture (RMP) and the Common Operation Picture (COP). Although there remains room for significant enhancements in the data communications with Trinity and Athena, the DFO ASP continues to be a valuable data contributor to DND.

Today, the program continues to provide surveillance of Canada's East and West Coasts under direction of DFO and DND.

A.2 World Approach

Canada is not alone, nor the only pioneer, in establishing relationships with the private sector for airborne surveillance services. Perhaps the most publicly visible example of a government engaged in a private sector contract for airborne surveillance services is the Australian Customs Service Coastwatch program. At a value of CDN$1 billion over 10 years, or CDN$100 million per year, this is the single largest example of private sector contracting for surveillance services in the World. The Canadian American Strategic Review (CASR) in 2002 published an article that pondered what Canada can learn from the Australian model:

http://www.sfu.ca/casr/ft-ozcusdd1.htm

Another example would be the Dutch Navy who recently contracted with Provincial Aerospace in Canada for two Dash-8 aircraft [49] to be operated over a 10-year period. The contract was internationally and competitively bid.

Figure 29: The Dutch Navy has contracted with Provincial Aerospace to provide turn-key surveillance services for a 10 year period [photo courtesy of Provincial Aerospace Ltd.].

The common element throughout the World with respect to these operations is that the missions do not otherwise require military assets to execute the mission. Although military assets are capable, they are generally too costly, or other military priorities are such that these assets are not readily available to participate in general law enforcement operations.

Private sector special mission operations are varied around the world, but generally are relationships that recognize the difference in establishing a military presence versus domestic presence requirements. Although they are varied, these can generally be classified as:

- Sovereignty patrols,
- Exclusive economic zone,
- Coastal zone monitoring,
- Fisheries enforcement,
- Pollution monitoring,
- Counter narcotics,
- Search and assist,
- Illegal migration, and
- Smuggling operations.

The general surveillance service model is also expanding to include several examples of the private sector participating in contractual relationships with their Governments for Search and Rescue operations. These operations are similar in nature to general surveillance operations, but basically require the contractor to meet the requirements of rescuing distressed people in the maritime environment.

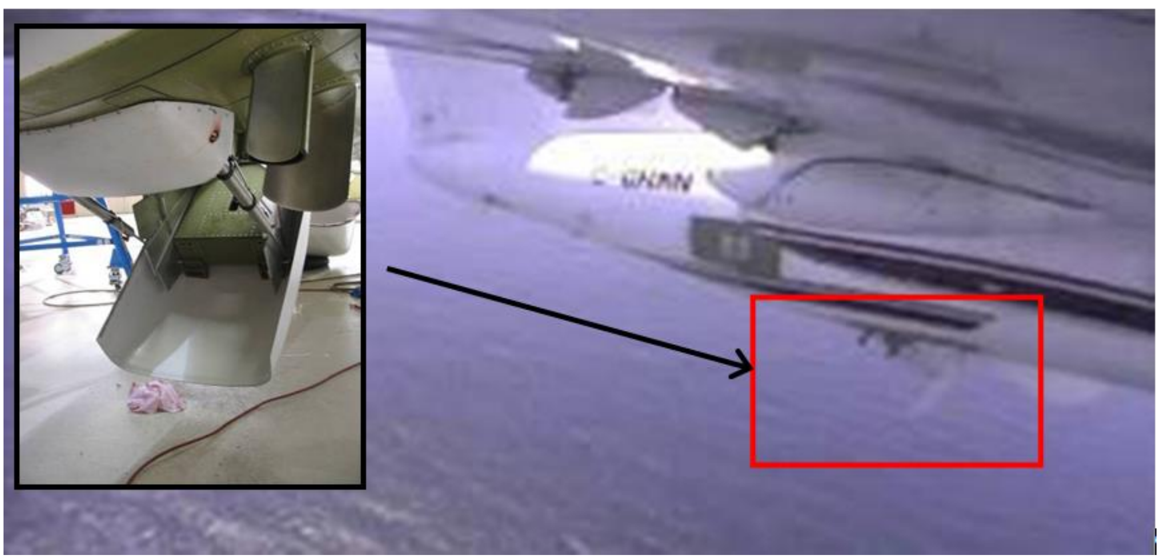


Figure 30: Dash-8 drop hatch/chute; Provincial Aerospace was the first company in the world to develop and implement this capability for the Dash-8 MPA platform

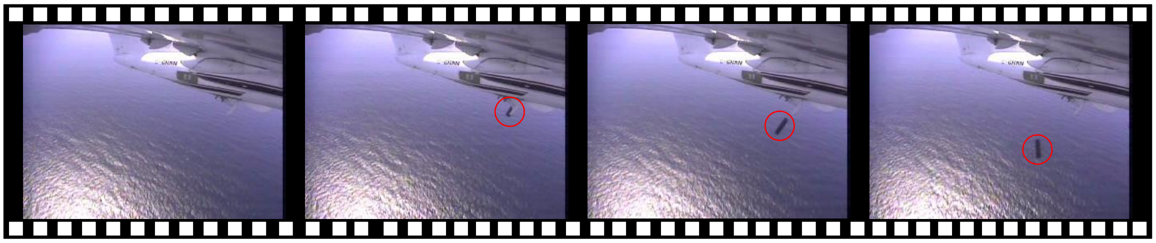


Figure 31: The Dash-8 drop hatch/chute capability designed by Provincial Aerospace is effective in all weather conditions and is suitable for the deployment of various stores including life rafts, smoke markers and oil sampling devices [photos courtesy of Provincial Aerospace Ltd.]

In conclusion, the Governments around the World that have participated in these of programs not only have directly received a cost-, and operationally-effective program, but also have contributed to a policy that fosters innovation in the private sector. Canada is a leading example of where its policies that established the DFO Air Surveillance Program have resulted in a private sector capability that is now considered by many to be amongst the best for technology and innovation in the World.

Figure 32: Canadian policy for contracting air surveillance services has resulted in significant innovation by the private sector, especially for the aerospace and defence international markets [Graphic courtesy of Provincial Aerospace Ltd.]

This page intentionally left blank.

Annex B Zone/Date Shipping Control Zones in the Arctic

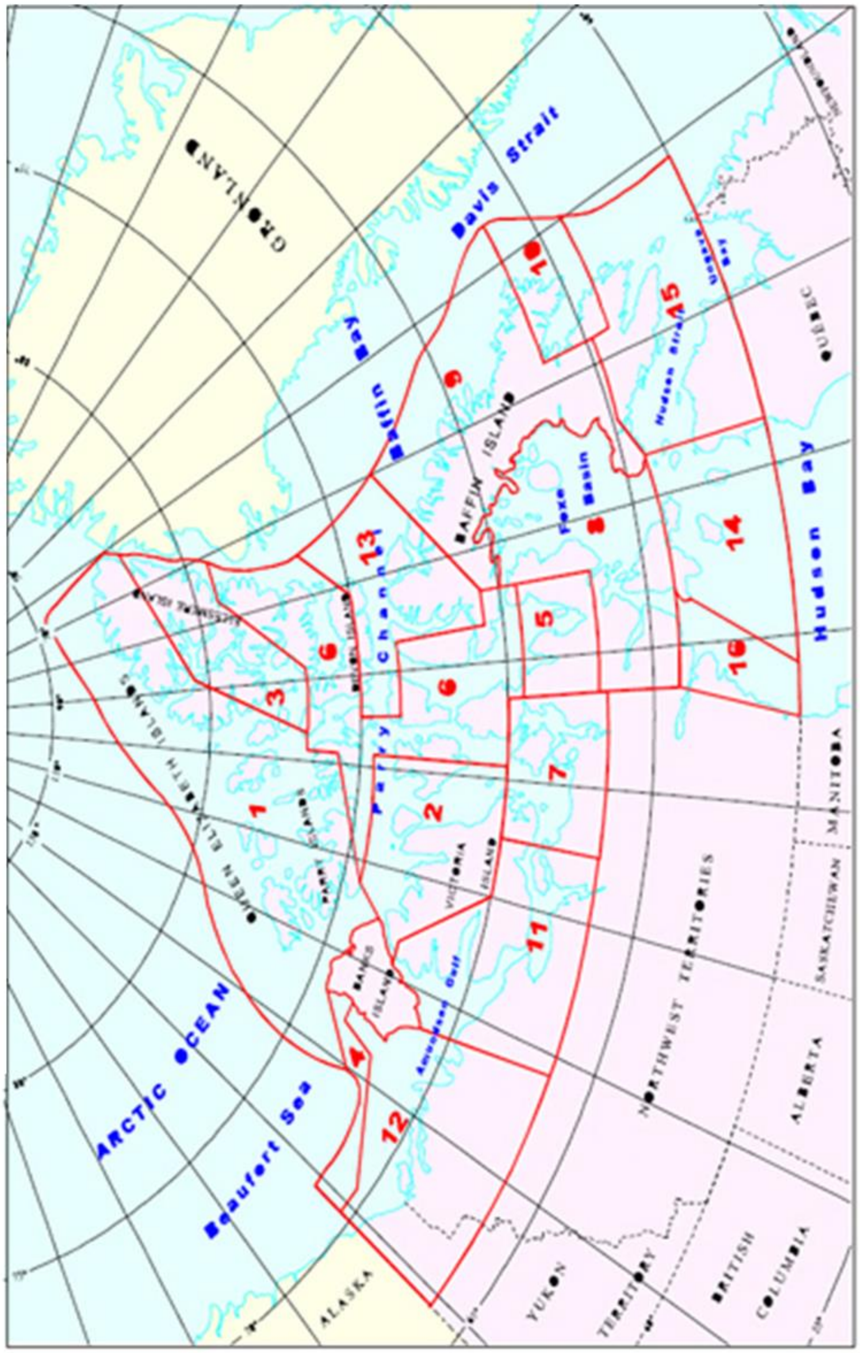


Figure 33: Shipping Safety Control Zones in the Arctic [5]

Table 8: Zone/Date Chart indicating when different vessel classes are allowed to enter the zones shown in Figure 33. The areas shaded in green represent year round access to that class of vessel, whereas red indicates the opposite. The columns shaded in gray indicated those associated with the most popular routes of the Northwest Passage.

Item	Category	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16
1	Arctic Class 10	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year
2	Arctic Class 8	July 1 Oct. 15	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year
3	Arctic Class 7	Aug. 1 Sep. 30	Aug. 1 Nov. 30	July 1 Dec.31	July 1 Dec.15	July 1 Dec.15	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year	All year
4	Arctic Class 6	Aug.15 Sep. 15	Aug.1 Oct.31	July 15 Nov.30	July 15 Nov.30	Aug. 1 Oct. 15	July 15 Feb.28	July 1 Mar.31	July 1 Mar.31	All year	All year	Jul. 1- Mar.31	All year	All year	All year	All year	All year
5	Arctic Class 4	Aug.15 Sep. 15	Aug.15 Oct.15	July 15 Oct.31	July 15 Nov.15	Aug.15 Sep.30	July 20 Dec.15	July 15 Jan.15	July 15 Jan.15	July 10 Mar.31	July 10 Feb.28	July 5 Jan.15	June 1 Jan. 31	June 1 Feb. 15	June 15 Feb. 15	June 15 Mar.15	June 1 Feb.15
6	Arctic Class 3	Aug.20- Sep. 15	Aug.20 Sep.30	July 25 Oct.15	July 20 Nov.5	Aug.20 Sep.25	Aug.1 Nov.30	July 20 Dec.15	July 20 Dec.31	July 20 Jan. 20	July 15 Jan. 25	July 5 Dec.15	June 10 Dec.31	June 10 Dec.31	June 20 Jan.10	June 20 Jan.31	June 5 Jan. 10
7	Arctic Class 2	No Entry	No Entry	Aug.15 Sep.30	Aug.1 Oct.31	No Entry	Aug.15 Nov.20	Aug.1 Nov.20	Aug.1 Nov.30	Aug.1 Dec.20	July25 Dec.20	July10 Nov.20	June15 Dec.5	June25 Nov.22	June25 Dec.10	June25 Dec.20	June 10 Dec.10
8	Arctic Class 1A	No Entry	No Entry	Aug.20 Sep.15	Aug.20 Sep.30	No Entry	Aug.25 Oct.31	Aug.10 Nov.5	Aug.10 Nov.20	Aug.10 Dec.10	Aug.1 Dec.10	July 15 Nov.10	July 1 Nov 10	July 15 Oct.31	July 1 Nov.30	July 1 Dec.10	June 20 Nov.30
9	Arctic Class 1	No Entry	No Entry	No Entry	No Entry	No Entry	Aug.25 Sep.30	Aug.10 Oct.15	Aug.10 Oct.31	Aug.10 Oct.31	Aug.1 Oct.31	July 15 Oct.20	July1 Oct.31	July15 Oct.15	July1 Nov.30	July 1 Nov.30	June 20 Nov.15
10	Type A	No Entry	No Entry	Aug.20 Sep. 10	Aug.20 Sep. 20	No Entry	Aug.15 Oct.15	Aug.1 Oct.25	Aug.1 Nov.10	Aug.1 Nov.20	July25 Nov.20	July 10 Oct.31	June15 Nov.10	June25 Oct. 22	June25 Nov.30	June25 Dec.5	June 20 Nov.20
11	Type B	No Entry	No Entry	Aug.20 Sep.5	Aug.20 Sep.15	No Entry	Aug.25 Sep.30	Aug.10 Oct.15	Aug10 Oct.31	Aug.10 Oct.31	Aug.1 Oct.31	July 15 Oct. 20	July 1 Oct.25	July 15 Oct.15	July 1 Nov.30	July 1 Nov.30	June20 Nov.10
12	Type C	No Entry	No Entry	No Entry	No Entry	No Entry	Aug.25 Sep. 25	Aug.10 Oct. 10	Aug.10 Oct.25	Aug.10 Oct.25	Aug.1 Oct.25	July 15 Oct.15	July 1 Oct.25	July 15 Oct.10	July 1 Nov.25	July 1 Nov.25	June 20 Nov.10
13	Type D	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug.10 Oct. 5	Aug.15 Oct.20	Aug.15 Oct.20	Aug.5 Oct.20	July 15 Oct.10	July1 Oct.20	July 30 Sep.30	July10 Nov.10	July5 Nov.10	July1 Oct.31
14	Type E	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug.10 Sep.30	Aug.20 Oct.20	Aug.20 Oct.15	Aug.10 Oct.20	July 15 Sep.30	July1 Oct.20	Aug.15 Sep.20	July20 Oct.31	July20 Nov.5	July1 Oct.31

Annex C Iridium SATCOM Systems

The following pages provide descriptions and specifications of certain SATCOM systems that make use of the Iridium satellite network to provide global voice and data communications solutions. The systems chosen to be described are just a representative list of capabilities, not an exhaustive selection. The systems that will be described are: AirSat I & II, and OpenPort

C.1 AirSat I & II

AirSat 1 is an approved aviation SATCOM system that uses GSM technology over the (global) Iridium satellite network. The following pages in this annex are screen captures of internet descriptions or brochures about the specifications and capabilities of the system.

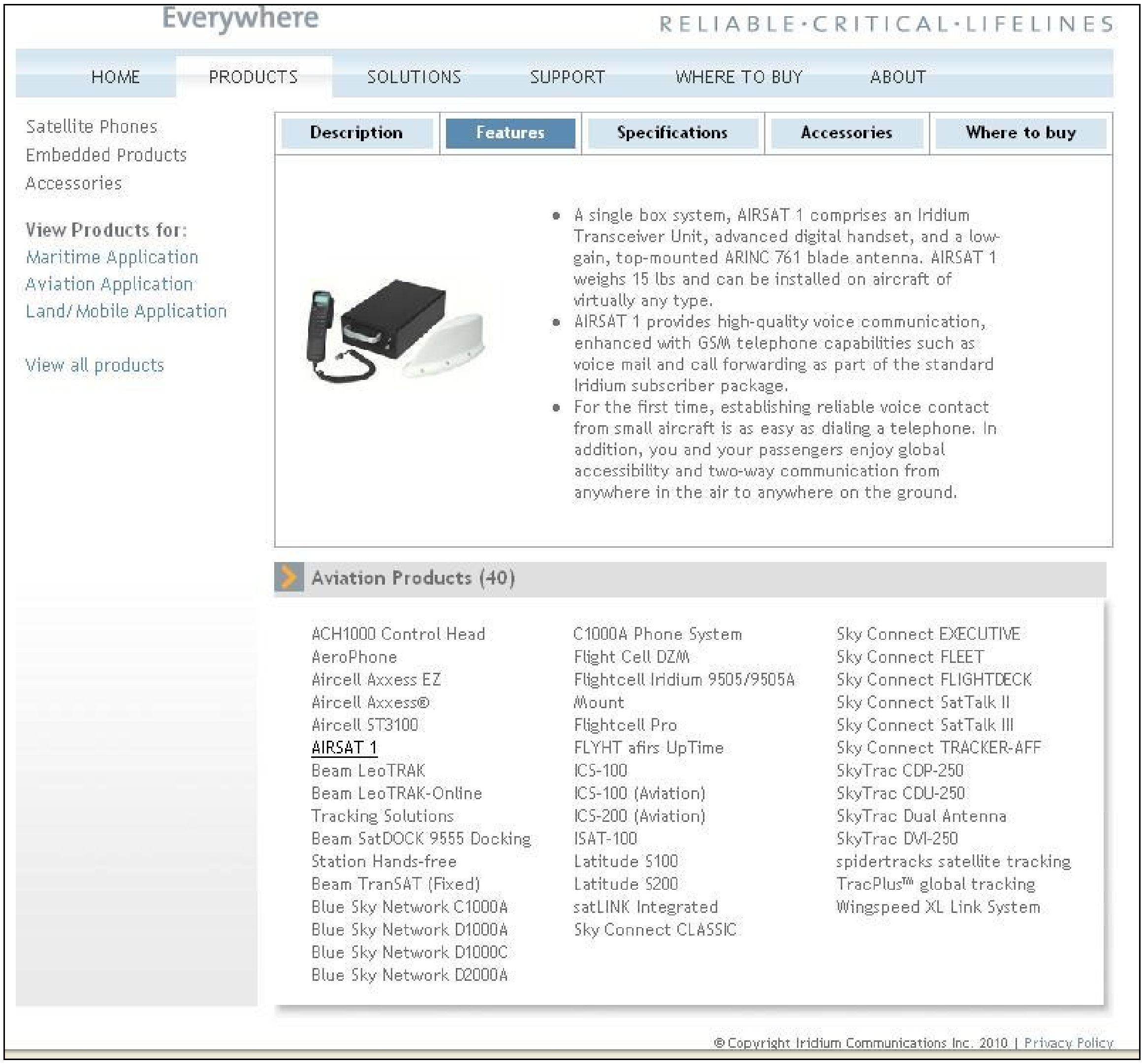


Figure 34: Features of the AirSat 1 SATCOM system

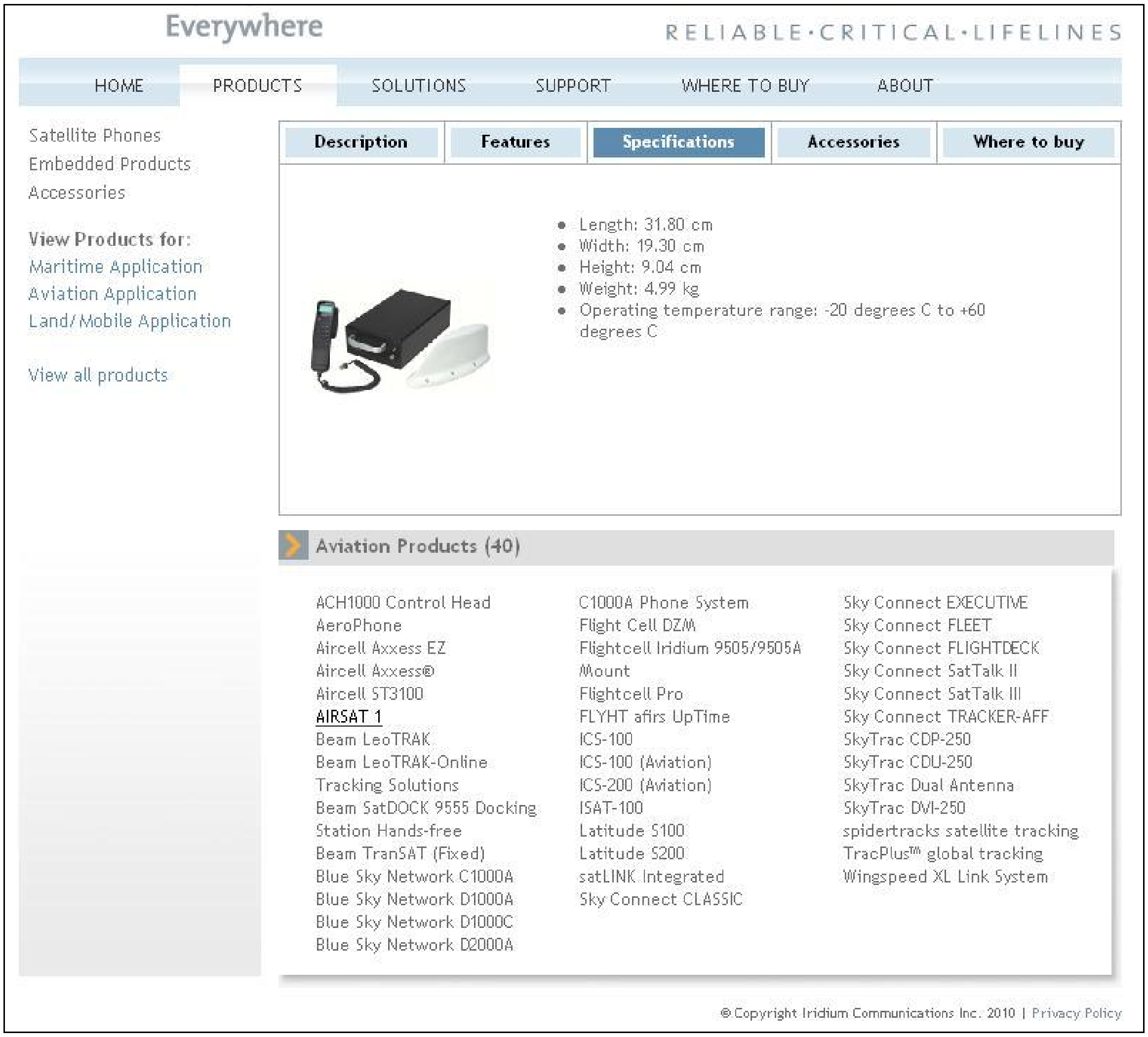


Figure 35: Specifications for the AirSat 1 SATCOM system.

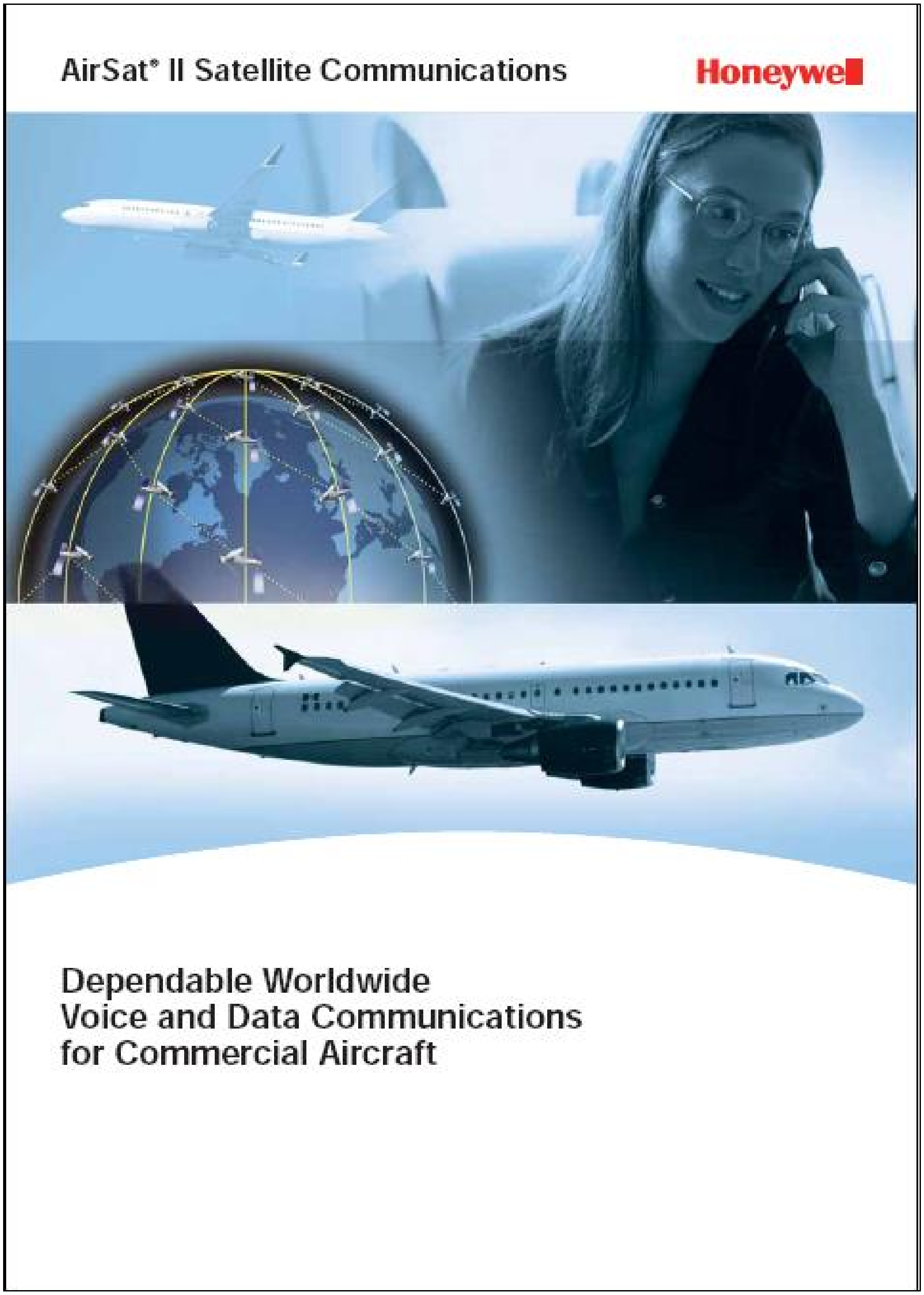
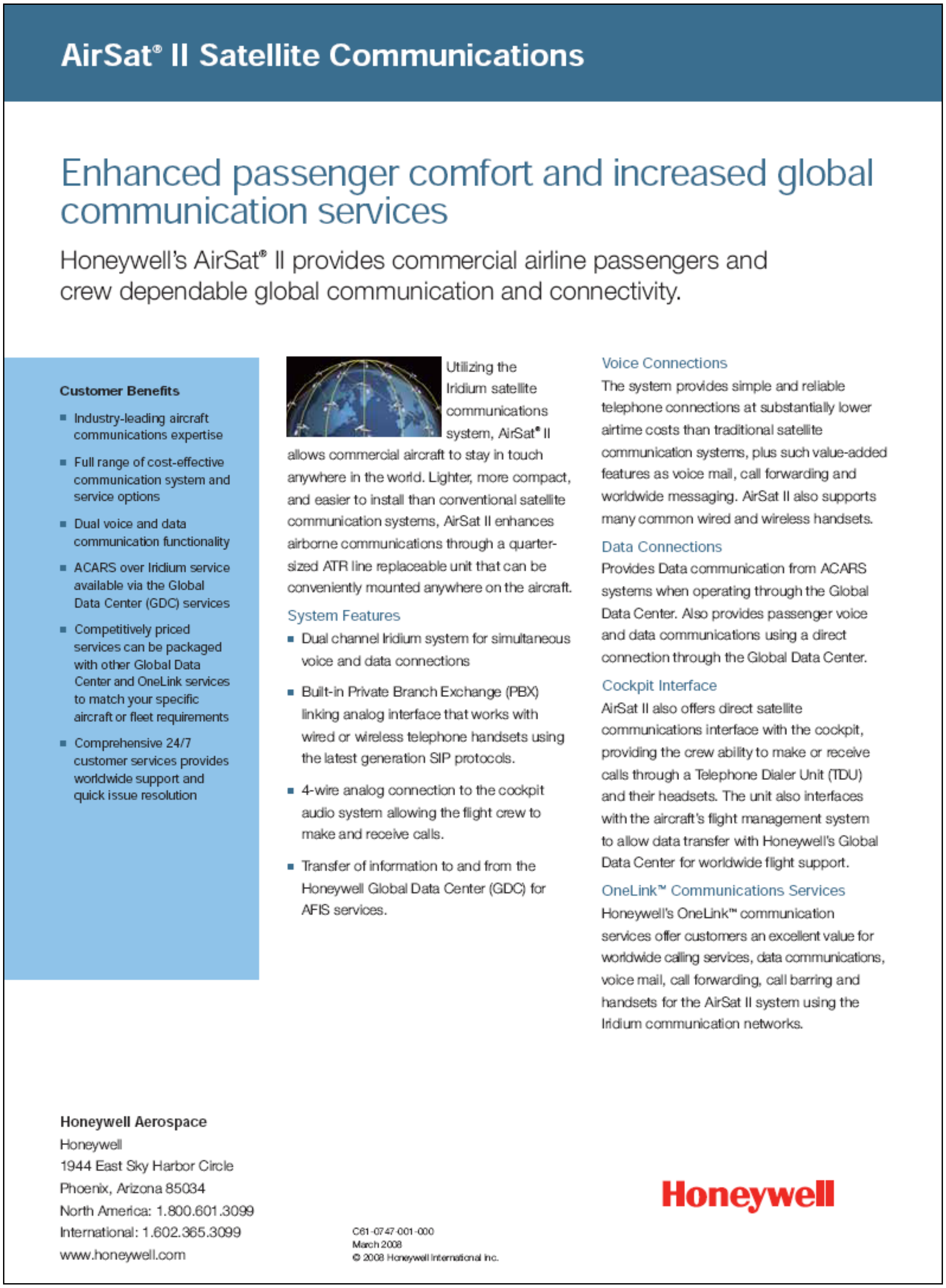


Figure 36: Cover page of the Honeywell AirSat II brochure [32]



AirSat® II Satellite Communications

Enhanced passenger comfort and increased global communication services

Honeywell's AirSat® II provides commercial airline passengers and crew dependable global communication and connectivity.

Customer Benefits

- Industry-leading aircraft communications expertise
- Full range of cost-effective communication system and service options
- Dual voice and data communication functionality
- ACARS over Iridium service available via the Global Data Center (GDC) services
- Competitively priced services can be packaged with other Global Data Center and OneLink services to match your specific aircraft or fleet requirements
- Comprehensive 24/7 customer services provides worldwide support and quick issue resolution

Utilizing the Iridium satellite communications system, AirSat® II allows commercial aircraft to stay in touch anywhere in the world. Lighter, more compact, and easier to install than conventional satellite communication systems, AirSat II enhances airborne communications through a quarter-sized ATR line replaceable unit that can be conveniently mounted anywhere on the aircraft.

System Features

- Dual channel Iridium system for simultaneous voice and data connections
- Built-in Private Branch Exchange (PBX) linking analog interface that works with wired or wireless telephone handsets using the latest generation SIP protocols.
- 4-wire analog connection to the cockpit audio system allowing the flight crew to make and receive calls.
- Transfer of information to and from the Honeywell Global Data Center (GDC) for AFIS services.

Voice Connections

The system provides simple and reliable telephone connections at substantially lower airtime costs than traditional satellite communication systems, plus such value-added features as voice mail, call forwarding and worldwide messaging. AirSat II also supports many common wired and wireless handsets.

Data Connections

Provides Data communication from ACARS systems when operating through the Global Data Center. Also provides passenger voice and data communications using a direct connection through the Global Data Center.

Cockpit Interface

AirSat II also offers direct satellite communications interface with the cockpit, providing the crew ability to make or receive calls through a Telephone Dialer Unit (TDU) and their headsets. The unit also interfaces with the aircraft's flight management system to allow data transfer with Honeywell's Global Data Center for worldwide flight support.

OneLink™ Communications Services

Honeywell's OneLink™ communication services offer customers an excellent value for worldwide calling services, data communications, voice mail, call forwarding, call barring and handsets for the AirSat II system using the Iridium communication networks.

Honeywell Aerospace
Honeywell
1944 East Sky Harbor Circle
Phoenix, Arizona 85034
North America: 1.800.601.3099
International: 1.602.365.3099
www.honeywell.com

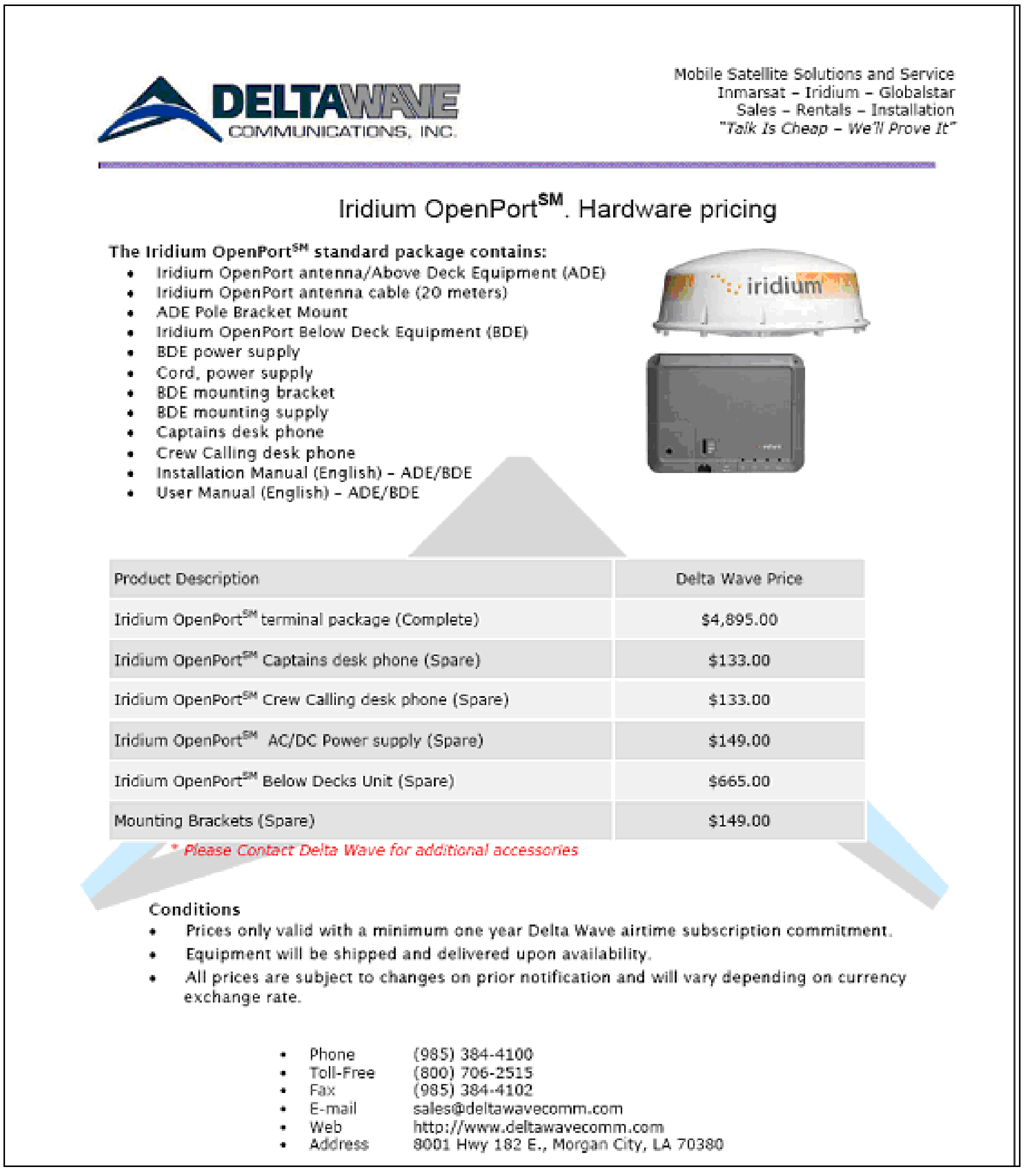
C61-0747-001-000
March 2008
© 2008 Honeywell International Inc.

Honeywell

Figure 37: Description page (2) of Honeywell AirSat II brochure [32].

C.2 OpenPort

Although OpenPort is actually an Iridium SATCOM product for marine applications, it is mentioned here as an indication of what should be possible for aviation applications, if it hasn't been implemented already. This system is advertised to have a potential data bandwidth of up to 128 kb/s. The following pages are screen captures of the OpenPort product brochure along with the service costs for different subscription options. Note that a similar system has also been developed for aeronautical applications using the Globalstar satellite network, but is currently only in the demonstration stage. As described in Annex C, it is also capable of up to 128 kb/s with possible extension to up to 600 kbps.



DELTAWAVE COMMUNICATIONS, INC.

Mobile Satellite Solutions and Service
Inmarsat – Iridium – Globalstar
Sales – Rentals – Installation
"Talk Is Cheap – We'll Prove It"

Iridium OpenPort[SM]. Hardware pricing

The Iridium OpenPort[SM] standard package contains:

- Iridium OpenPort antenna/Above Deck Equipment (ADE)
- Iridium OpenPort antenna cable (20 meters)
- ADE Pole Bracket Mount
- Iridium OpenPort Below Deck Equipment (BDE)
- BDE power supply
- Cord, power supply
- BDE mounting bracket
- BDE mounting supply
- Captains desk phone
- Crew Calling desk phone
- Installation Manual (English) – ADE/BDE
- User Manual (English) – ADE/BDE

Product Description	Delta Wave Price
Iridium OpenPort[SM] terminal package (Complete)	$4,895.00
Iridium OpenPort[SM] Captains desk phone (Spare)	$133.00
Iridium OpenPort[SM] Crew Calling desk phone (Spare)	$133.00
Iridium OpenPort[SM] AC/DC Power supply (Spare)	$149.00
Iridium OpenPort[SM] Below Decks Unit (Spare)	$665.00
Mounting Brackets (Spare)	$149.00

* Please Contact Delta Wave for additional accessories

Conditions

- Prices only valid with a minimum one year Delta Wave airtime subscription commitment.
- Equipment will be shipped and delivered upon availability.
- All prices are subject to changes on prior notification and will vary depending on currency exchange rate.

- Phone (985) 384-4100
- Toll-Free (800) 706-2515
- Fax (985) 384-4102
- E-mail sales@deltawavecomm.com
- Web http://www.deltawavecomm.com
- Address 8001 Hwy 182 E., Morgan City, LA 70380

Figure 38: First page of the OpenPort product brochure [33].

DELTAWAVE COMMUNICATIONS, INC.

Mobile Satellite Solutions and Service
Inmarsat – Iridium – Globalstar
Sales – Rentals – Installation
"Talk Is Cheap – We'll Prove It"

Iridium OpenPort^{SM}. Airtime pricing – End User

Voice minutes included				**0**	**100**	**200**	**300**
Price per minute (IOP-PSTN)		**Out-bundle**		$1.50	1.16	1.05	0.84
MByte included	**Speed (kbps)**	**Price per MB**		**Monthly Fees**			
		In-bundle	**Out-bundle**				
0	32	$0.00	$22.15	$43.85	$116.00	$210.50	$252.75
10	32	$15.45	$16.60	$158.00	$274.00	$368.50	$410.50
25	32	$13.35	$14.35	$351.00	$467.00	$561.50	$603.50
50	32	$11.65	$12.55	$614.00	$730.00	$824.50	$866.75
100	32	$8.00	$8.60	$877.00	$993.00	$1,088.00	$1,030.00
150	32	$6.40	$6.85	$1,053.00	$1169.00	1,263.50	$1,305.50

** Pricing is stated in USD$/month/per bundle*

9.6 kbps	only available for 0MB/0 min package	
32 kbps	standard bandwidth	
64 kbps	standard 32kbps package, monthly surcharge to increase to 64 kbps:	$133.50
128 kbps	standard 32kbps package, monthly surcharge to increase to 128 kbps:	$350.00

Other charges (not in package)	**$ per min**
Iridium to Iridium	$0.84
Iridium to other satellites	$12.32
Iridium to voicemail	$0.84
Iridium 2-stage dialing	$1.96
Charge per voice line only applied for 0MB/0min package	$7.15
Activation fee	waived till Dec. 31, 2008
Pooling Fee per SIM per month	$39.95
Roll-over Fee per SIM per month	$60.00
Increments voice	20 sec
Increments data	1 Byte

Commitment length	**Discount**	**Early termination charge**
1 year	0%	$357
2 years	5%	$715
3 years	10%	$1070

** Discount applies to monthly bundle fees only, no discount on overage rates*
*** Pricing is pursuant to a minimum one year commitment*

DWCOPENPORTPRICING091508

- Phone (985) 384-4100
- Toll-Free (800) 706-2515
- Fax (985) 384-4102
- E-mail sales@deltawavecomm.com
- Web http://www.deltawavecomm.com
- Address 8001 Hwy 182 E., Morgan City, LA 70380

Figure 39: Second page of the OpenPort product brochure [33].

This page intentionally left blank.

Annex D Globalstar SATCOM Systems

Figure 40: Medium Data Rate SATCOM (Demonstration) System capable of up to 128 kb/s with possible extension to 600kb/s [34].

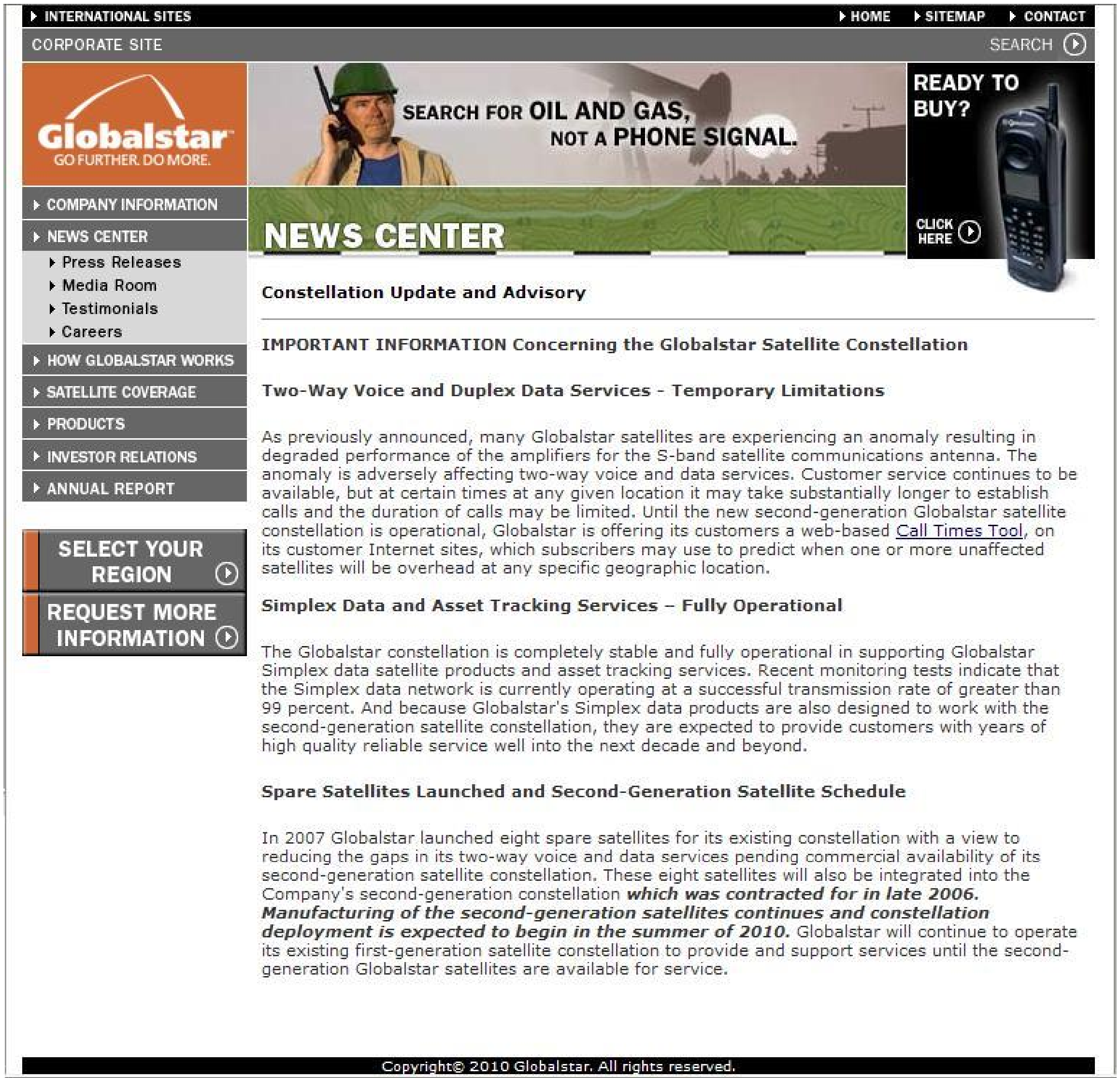
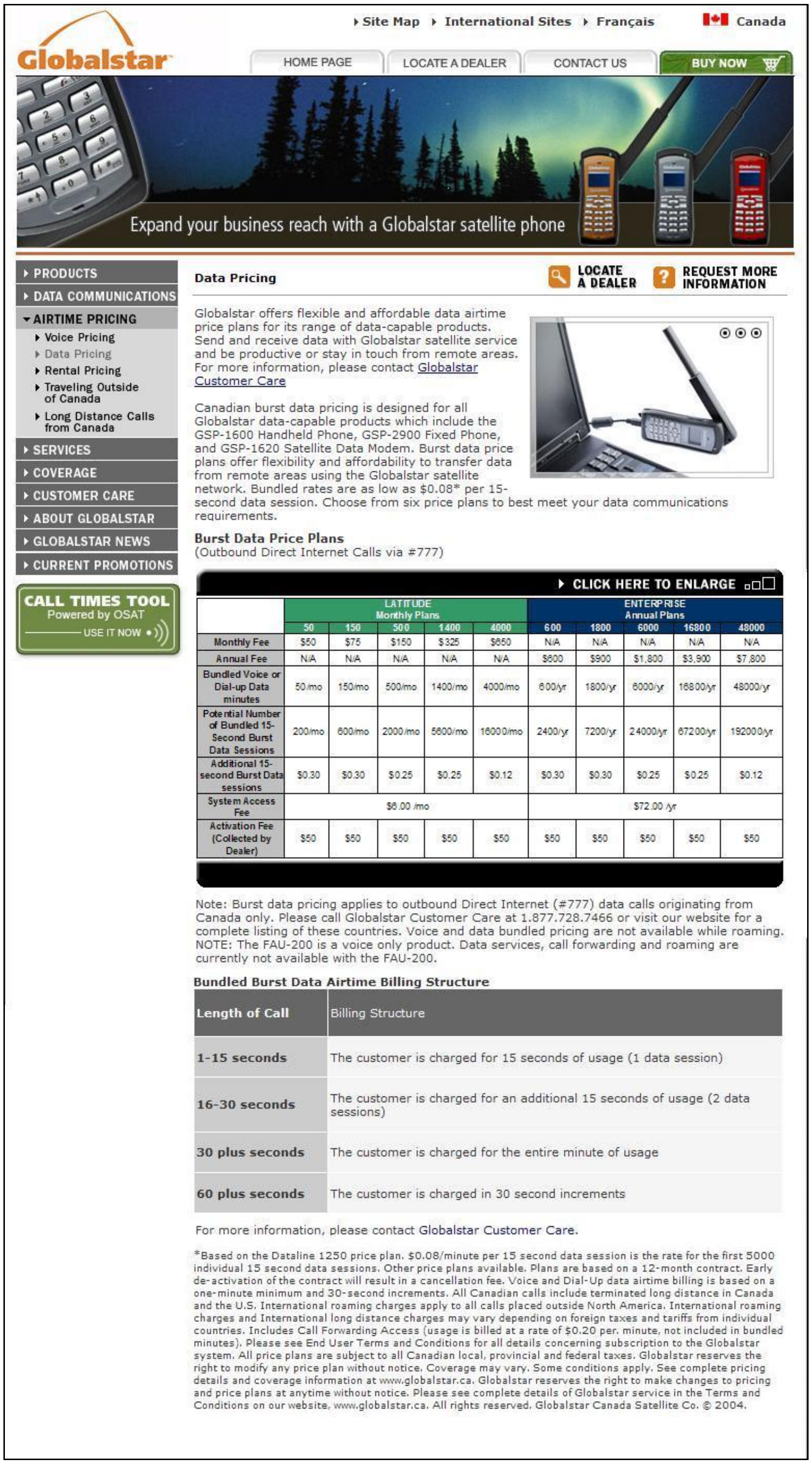


Figure 41: Advisory from Globalstar regarding Temporary Limitations for Two-Way Voice and Duplex Data Services until at least the summer of 2010 [35].


Site Map | International Sites | Français | Canada

Globalstar

HOME PAGE | LOCATE A DEALER | CONTACT US | BUY NOW

Expand your business reach with a Globalstar satellite phone

PRODUCTS
DATA COMMUNICATIONS
AIRTIME PRICING
- Voice Pricing
- Data Pricing
- Rental Pricing
- Traveling Outside of Canada
- Long Distance Calls from Canada

SERVICES
COVERAGE
CUSTOMER CARE
ABOUT GLOBALSTAR
GLOBALSTAR NEWS
CURRENT PROMOTIONS

CALL TIMES TOOL
Powered by OSAT
USE IT NOW

Data Pricing

LOCATE A DEALER | REQUEST MORE INFORMATION

Globalstar offers flexible and affordable data airtime price plans for its range of data-capable products. Send and receive data with Globalstar satellite service and be productive or stay in touch from remote areas. For more information, please contact Globalstar Customer Care

Canadian burst data pricing is designed for all Globalstar data-capable products which include the GSP-1600 Handheld Phone, GSP-2900 Fixed Phone, and GSP-1620 Satellite Data Modem. Burst data price plans offer flexibility and affordability to transfer data from remote areas using the Globalstar satellite network. Bundled rates are as low as $0.08* per 15-second data session. Choose from six price plans to best meet your data communications requirements.

Burst Data Price Plans
(Outbound Direct Internet Calls via #777)

CLICK HERE TO ENLARGE

	LATITUDE Monthly Plans					ENTERPRISE Annual Plans				
	50	150	500	1400	4000	600	1800	6000	16800	48000
Monthly Fee	$50	$75	$150	$325	$650	N/A	N/A	N/A	N/A	N/A
Annual Fee	N/A	N/A	N/A	N/A	N/A	$600	$900	$1,800	$3,900	$7,800
Bundled Voice or Dial-up Data minutes	50/mo	150/mo	500/mo	1400/mo	4000/mo	600/yr	1800/yr	6000/yr	16800/yr	48000/yr
Potential Number of Bundled 15-Second Burst Data Sessions	200/mo	600/mo	2000/mo	5600/mo	16000/mo	2400/yr	7200/yr	24000/yr	67200/yr	192000/yr
Additional 15-second Burst Data sessions	$0.30	$0.30	$0.25	$0.25	$0.12	$0.30	$0.30	$0.25	$0.25	$0.12
System Access Fee	$6.00 /mo					$72.00 /yr				
Activation Fee (Collected by Dealer)	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50

Note: Burst data pricing applies to outbound Direct Internet (#777) data calls originating from Canada only. Please call Globalstar Customer Care at 1.877.728.7466 or visit our website for a complete listing of these countries. Voice and data bundled pricing are not available while roaming. NOTE: The FAU-200 is a voice only product. Data services, call forwarding and roaming are currently not available with the FAU-200.

Bundled Burst Data Airtime Billing Structure

Length of Call	Billing Structure
1-15 seconds	The customer is charged for 15 seconds of usage (1 data session)
16-30 seconds	The customer is charged for an additional 15 seconds of usage (2 data sessions)
30 plus seconds	The customer is charged for the entire minute of usage
60 plus seconds	The customer is charged in 30 second increments

For more information, please contact Globalstar Customer Care.

*Based on the Dataline 1250 price plan. $0.08/minute per 15 second data session is the rate for the first 5000 individual 15 second data sessions. Other price plans available. Plans are based on a 12-month contract. Early de-activation of the contract will result in a cancellation fee. Voice and Dial-Up data airtime billing is based on a one-minute minimum and 30-second increments. All Canadian calls include terminated long distance in Canada and the U.S. International roaming charges apply to all calls placed outside North America. International roaming charges and International long distance charges may vary depending on foreign taxes and tariffs from individual countries. Includes Call Forwarding Access (usage is billed at a rate of $0.20 per. minute, not included in bundled minutes). Please see End User Terms and Conditions for all details concerning subscription to the Globalstar system. All price plans are subject to all Canadian local, provincial and federal taxes. Globalstar reserves the right to modify any price plan without notice. Coverage may vary. Some conditions apply. See complete pricing details and coverage information at www.globalstar.ca. Globalstar reserves the right to make changes to pricing and price plans at anytime without notice. Please see complete details of Globalstar service in the Terms and Conditions on our website, www.globalstar.ca. All rights reserved. Globalstar Canada Satellite Co. © 2004.

Figure 42: Globalstar Price Plan [36]

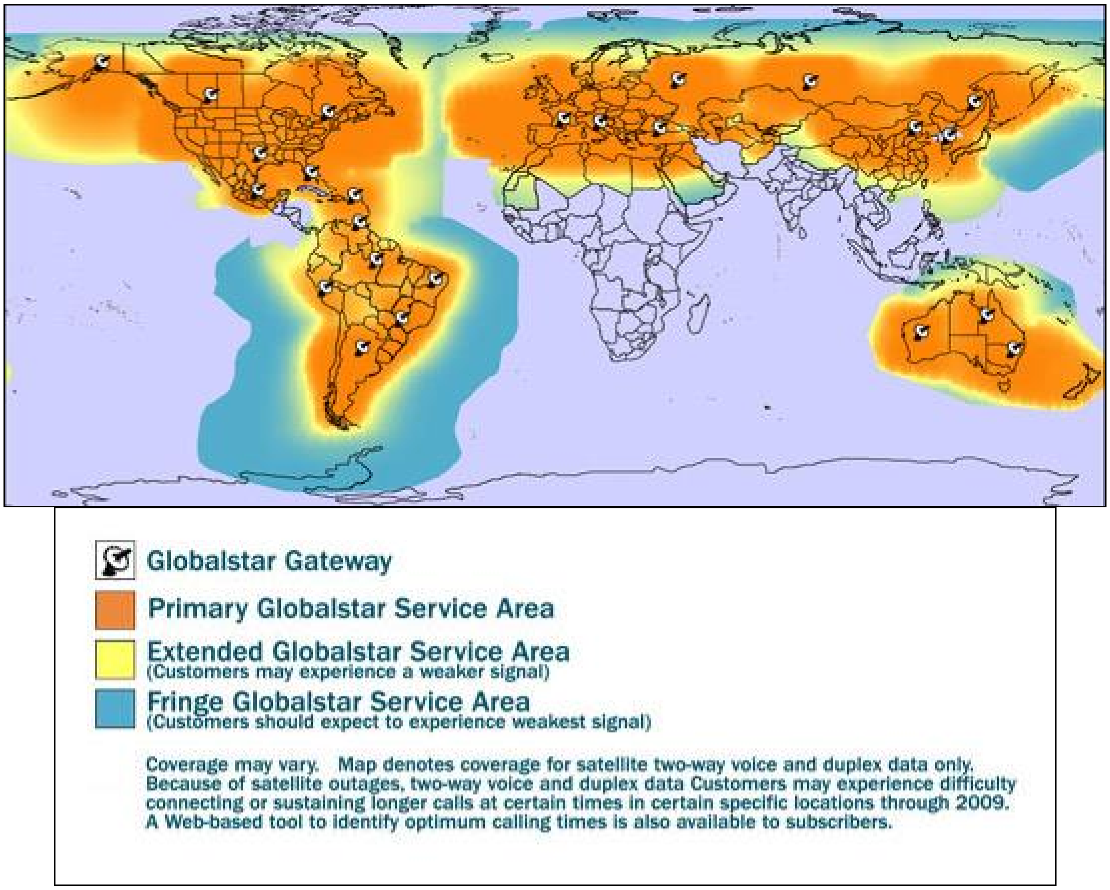


Figure 43: Globalstar world coverage map [37]; notice that coverage in the High Arctic is not very good, despite the fact that the satellite network employs polar orbiting satellites.

Annex E Inmarsat SATCOM

E.1 Classic Aero and Swift 64

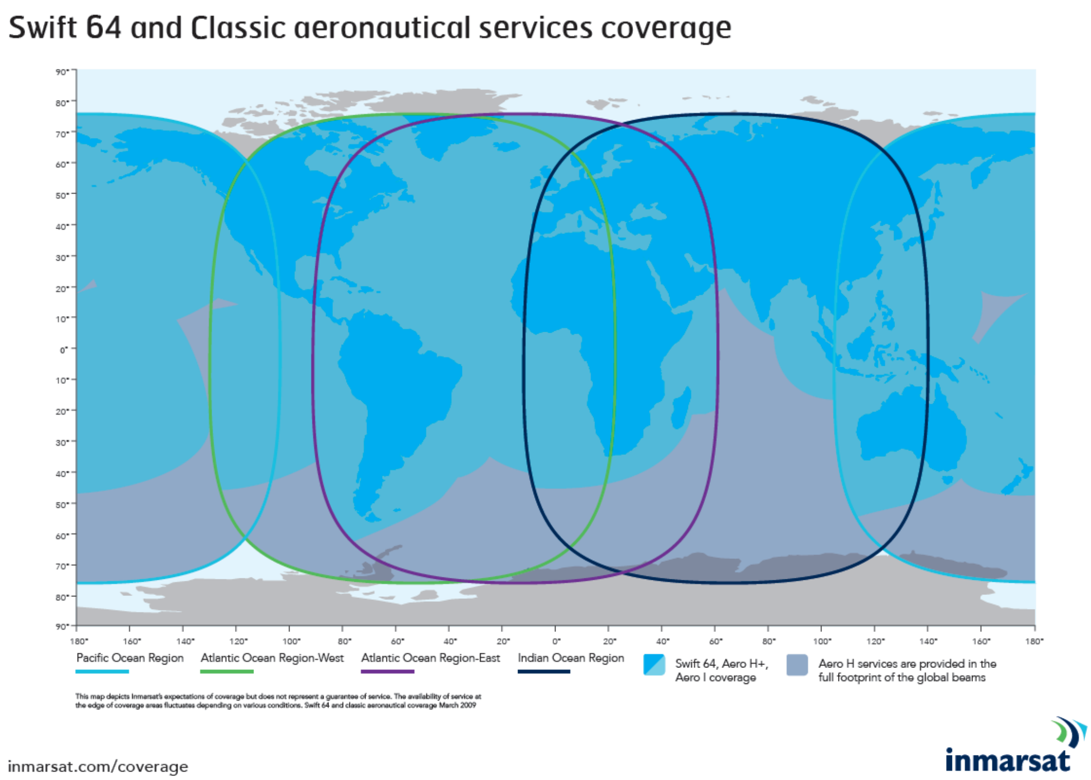


Figure 44: Coverage zones for Swift 64 (64 kbps) and Classic (600bps to 10.5 kbps) SATCOM services via Inmarsat [38] .

Aero Classic services - Inmarsat

Page 1 of 1

Search Site | Search

Partner Login

inmarsat

Services Support About Inmarsat Partners

You are here : Home Services Aeronautical Classic Aero

Aeronautical

Sectors

Air Transport
Business aviation
Government

Services

SwiftBroadband
Swift 64
Classic services

Safety

Air safety
The future

News
How to buy

Classic services

Aviation standards

Inmarsat's Classic range of aeronautical services supports high-quality voice, low-speed data and safety communications. They are used by most of the world's airlines and corporate jet operators, as well as governments for VIP aircraft, coastguard and defence agencies.

There are six services, which vary in capability, coverage, equipment size and cost:

Aero H
Multi-channel voice, 10.5kbps fax and data, delivered via a high-gain antenna within the satellites' global beams. ICAO approved for safety services.

Aero H+
Multi-channel voice, 10.5kbps fax and data, delivered via a high-gain antenna within the spot beams of the Inmarsat-3 satellites and the full footprint of the Inmarsat-4 Atlantic Ocean Region (AOR) satellite, at a lower cost per connection. ICAO approved for safety services.

Aero I
Multi-channel voice, 4.8kbps circuit-mode data and fax, delivered via an intermediate-gain antenna. Available in the spot beams of the Inmarsat-3 satellites. ICAO approved for safety services. Also supports low-speed packet data supported in both the Inmarsat-3 spot beams and in the full footprint of the Inmarsat-4 satellites.

Aero L
Global data communications at 600 to 1200bps, principally to support air traffic control and airline operations. Supports Acars/Aircom messaging. ICAO approved for safety services.

Mini M Aero
Single-channel voice, fax or 2400bps data, for general aviation and smaller corporate aircraft. Supports STU-III encrypted voice.

Aero C
Supports two-way 600bps store-and-forward data messaging, polling and integrated GPS position-reporting for non-safety-related purposes.

Coverage

Inmarsat's Classic services are delivered within the spot beams of the Inmarsat-3 satellites and the whole footprint of the Inmarsat-4 footprint in the Atlantic Ocean Region.

Safety

Privacy policy Terms & conditions
Acceptable use Subscribe
Contact us Twitter

http://www.inmarsat.com/Services/Aeronautical/Classic_Aero/default.aspx?language=EN&textonly=False 08/01/2010

Figure 45: Classic Aeronautical SATCOM services (600 bps to 10.5 kbps) [39].

Swift 64

inmarsat

Swift 64 provides ISDN, Mobile Packet Data Service (MPDS) and a high quality voice service.

ISDN and packet-data

Swift 64 is a circuit-switched, mobile ISDN service providing the same high quality and guaranteed speed as terrestrial ISDN. Higher bandwidth can be achieved by bonding up to four 64kbps channels together.

Swift 64 also offers a Mobile Packet Data Service (MPDS), which provides the economy and flexibility of 'always-on' packet data connections.

In addition, it provides a high quality voice service with the same functionality as land-based fixed phone services.

The end-user experience depends on the native performance of Swift 64, as well as any performance-enhancing technologies that are being used eg. data compression, IP and application optimisation.

Features

The Swift 64 service has the following features:

- Dedicated circuit-mode (mobile ISDN), packet-mode (MPDS) connections or high quality voice channels
- One, two or four-channel avionics
- 64kbps data throughput per ISDN channel
- Optional bonding of channels to yield up to 256kbps – can be increased further through data compression
- Three data formats: ISDN, Unrestricted Digital Information (UDI) and packet-data (TCP/IP)
- Standalone or simultaneous operation with Inmarsat Aero H/H+ through the same high-gain antenna
- Support for high-assurance applications, including NATO secret and NSA Type-1 encryption systems providing remote mobile access to classified networks – STU-III/IIb, STE, KIV-7, Brent and HAIPE devices including KG-175 TACLANE, KG-235 Sectéra, KG-250 Altasec, subject to verification testing

The mobile satellite company™

Figure 46: First Page of the brochure [40] for Inmarsat SWIFT64 SATCOM option for avionic application; system provides up to 64kbps, but since it is a geosynchronous satellite, it has limited coverage in the Arctic

Requirements

The following is required to operate Swift 64:

- Swift 64 avionics – the satellite modem to access the service
- A high-gain aircraft antenna capable of receiving Swift 64 and related equipment eg. Diplexer, LNA, HPA and cabling
- An agreement with a service provider

Aircraft without an Inmarsat system

For new aircraft, airframe manufacturers can advise if Swift 64 avionics are an option either as SFE or BFE. For aircraft already in use, Swift 64 avionics manufacturers can recommend equipment and advise on STC status.

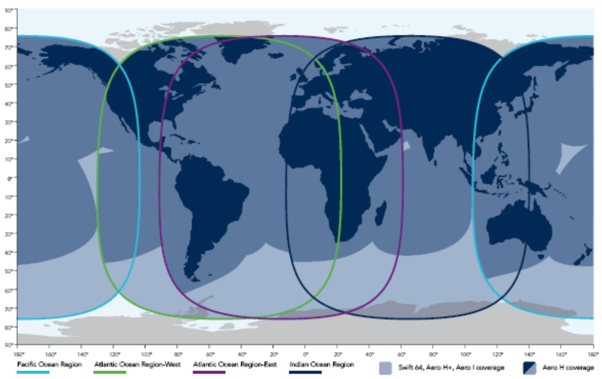
Upgrading an existing Inmarsat installation

Users of Inmarsat classic services, such as Aero H/H+, can add Swift 64 to their installation depending on the equipment already installed on the aircraft.

Consultation with the relevant avionics and antenna manufacturers is necessary to establish the appropriate upgrade path for each particular aircraft configuration.

Coverage

Currently, Swift 64 uses the spot beams of the Inmarsat-3 (I-3) satellites and the I-4 AOR satellite. When the I-4 Americas satellite (formerly the I-4 AOR) is deactivated during the repositioning process, Swift 64 traffic in the AOR will be transferred permanently back to the I-3. At this time, Inmarsat will optimise the I-3 spot beam coverage in the AOR-W.



This map depicts Inmarsat's targeted area of coverage once services have been transferred from the I-4 satellite to the I-3 satellite in the Atlantic Ocean Region West. Actual coverage in this area will be confirmed once the services have been transferred and testing is complete. Please refer to inmarsat.com/coverage for further information on timescales. This map does not represent a guarantee of service. The availability of service at the edge of coverage areas fluctuates depending on a variety of conditions.

Applications

Swift 64 supports a wide range of crew and passenger applications:

Crew

- Voice communications
- Electronic Flight Bag (EFB), flight plan, weather and chart updates
- General operational planning
- Crew reporting and general administration

Passengers

- Telephony: in-seat, mobile, VoIP and text messaging
- Email, intranet, internet and instant messaging
- Secure VPN access
- Large file transfer – presentations, graphics, images
- Videoconferencing
- In-flight news updates

How to buy

Avionics/Antennas

Swift 64 avionics are offered by Chelton Satcom (avionics and antennas), Esterline/CMC (antennas), EMS Technologies (avionics and antennas), Honeywell (avionics), Rockwell Collins (avionics), TECOM Industries (antennas), Thales (avionics) and Thrane & Thrane (avionics).

Service provision

Aircraft operators must contract with an Inmarsat service provider. The service provider invoices for the service, either on a data volume or time basis, depending on the service used. Visit our website for contact details.

inmarsat.com/swift64

Figure 47 Second page of SWIFT64 product brochure [40].

E.2 SwiftBroadband (BGAN)

INMARSAT SwiftBroadband is a Broadband Global Area Network (BGAN) service usually priced according to throughput rather than a per-minute charge. Typical prices for BGAN service (less equipment costs) is shown at the end of this section, ranging from $5 to $8 per Megabyte.

SwiftBroadband

inmarsat

SwiftBroadband provides voice and high-speed data, simultaneously, through a single installation on a global basis.

High-speed, IP-based voice and data

SwiftBroadband is an IP-based packet-switched service that provides a symmetric 'always-on' data connection of up to 432kbps per channel. In Standard IP mode, the service is shared with other concurrent users of the system, providing a 'best effort' service. SwiftBroadband can also provide a pre-determined quality of service through streaming classes of 32, 64 or 128kbps. Higher bandwidth can be achieved by combining channels, currently up to two per installation.

SwiftBroadband provides a high-quality voice channel with the full functionality of land-based fixed phone services and a generic SMS service. For backward compatibility, it also provides a circuit-switched ISDN service.

It is possible to have a combination of multiple packet-switched services with one circuit-switched service active at the same time.

The end-user experience depends on the native performance of SwiftBroadband, as well as any performance-enhancing technologies that are being used eg. data compression, IP and application optimisation.

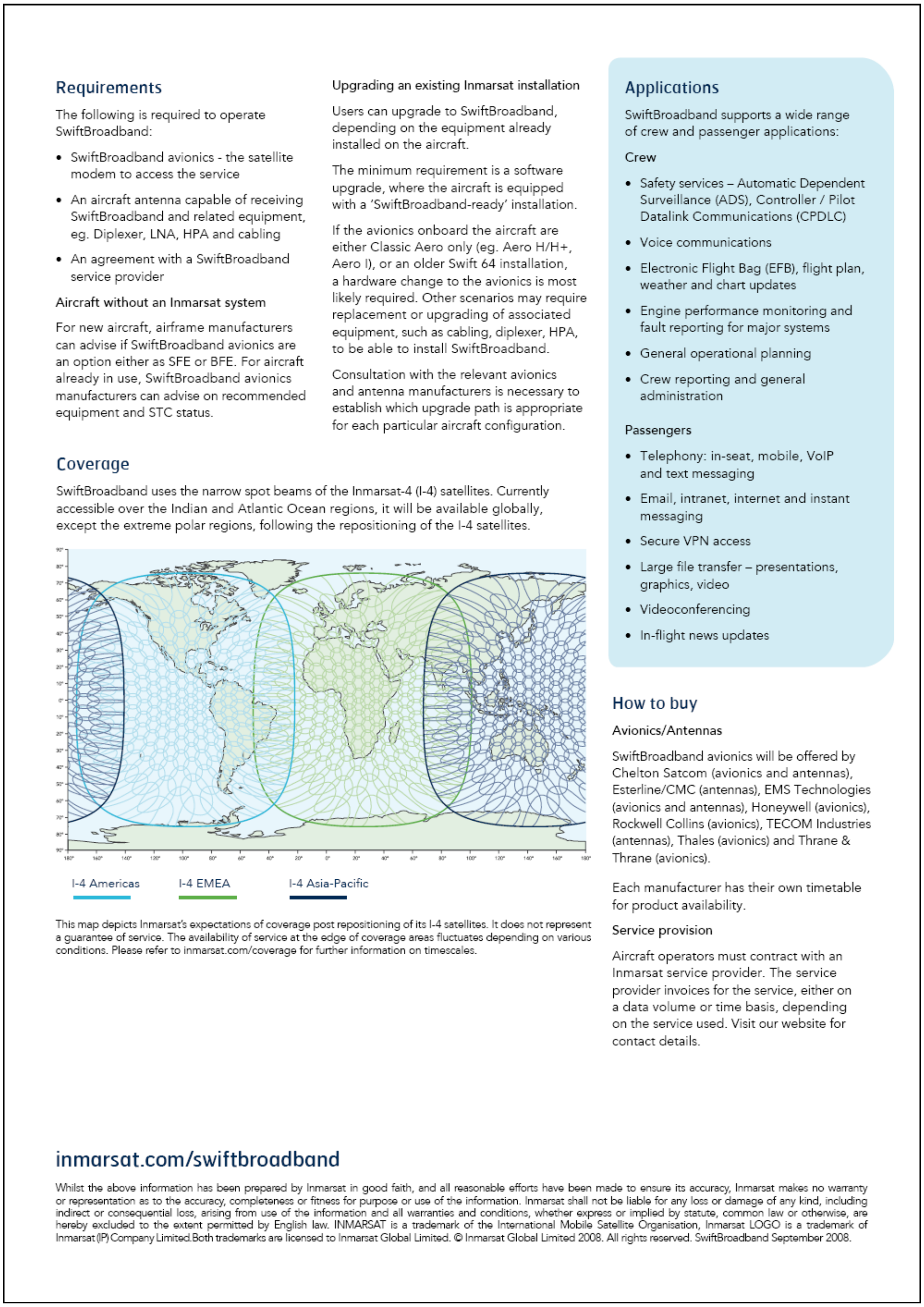
Features

- Standard IP data – currently up to two channels per aircraft:
  - Up to 432kbps per channel over a high-gain antenna
  - Up to 332kbps over an intermediate-gain antenna
- IP data streaming on demand at 32, 64, 128kbps – can be combined for higher rates
- Simultaneous voice and high-speed data:
  - Packet data (TCP/IP) and ISDN
  - Circuit-switched voice and VoIP
- Standalone or simultaneous operation with Inmarsat's Aero H/H+ and Swift 64 services
- GPRS and UMTS compatible
- Compliant with ARINC 781
- Support for high-assurance applications, including NATO secret and NSA Type-1 encryption systems providing remote mobile access to classified networks – STU-III/IIb, STE, KIV-7, Brent and HAIPE devices including KG-175 TACLANE, KG-235 Sectéra, KG-250 Altasec, subject to verification testing

The mobile satellite company™

Figure 48 First page of Inmarsat brochure [41] for the SwiftBroadband SATCOM option for avionics applications. It is supposedly capable of up to 432kbps depending on the antenna &

coverage; although better than for Swift64, in the High Arctic it is still on the edge of the coverage zone.



Requirements

The following is required to operate SwiftBroadband:

- SwiftBroadband avionics - the satellite modem to access the service
- An aircraft antenna capable of receiving SwiftBroadband and related equipment, eg. Diplexer, LNA, HPA and cabling
- An agreement with a SwiftBroadband service provider

Aircraft without an Inmarsat system

For new aircraft, airframe manufacturers can advise if SwiftBroadband avionics are an option either as SFE or BFE. For aircraft already in use, SwiftBroadband avionics manufacturers can advise on recommended equipment and STC status.

Upgrading an existing Inmarsat installation

Users can upgrade to SwiftBroadband, depending on the equipment already installed on the aircraft.

The minimum requirement is a software upgrade, where the aircraft is equipped with a 'SwiftBroadband-ready' installation.

If the avionics onboard the aircraft are either Classic Aero only (eg. Aero H/H+, Aero I), or an older Swift 64 installation, a hardware change to the avionics is most likely required. Other scenarios may require replacement or upgrading of associated equipment, such as cabling, diplexer, HPA, to be able to install SwiftBroadband.

Consultation with the relevant avionics and antenna manufacturers is necessary to establish which upgrade path is appropriate for each particular aircraft configuration.

Coverage

SwiftBroadband uses the narrow spot beams of the Inmarsat-4 (I-4) satellites. Currently accessible over the Indian and Atlantic Ocean regions, it will be available globally, except the extreme polar regions, following the repositioning of the I-4 satellites.

I-4 Americas
I-4 EMEA
I-4 Asia-Pacific

This map depicts Inmarsat's expectations of coverage post repositioning of its I-4 satellites. It does not represent a guarantee of service. The availability of service at the edge of coverage areas fluctuates depending on various conditions. Please refer to inmarsat.com/coverage for further information on timescales.

Applications

SwiftBroadband supports a wide range of crew and passenger applications:

Crew

- Safety services – Automatic Dependent Surveillance (ADS), Controller / Pilot Datalink Communications (CPDLC)
- Voice communications
- Electronic Flight Bag (EFB), flight plan, weather and chart updates
- Engine performance monitoring and fault reporting for major systems
- General operational planning
- Crew reporting and general administration

Passengers

- Telephony: in-seat, mobile, VoIP and text messaging
- Email, intranet, internet and instant messaging
- Secure VPN access
- Large file transfer – presentations, graphics, video
- Videoconferencing
- In-flight news updates

How to buy

Avionics/Antennas

SwiftBroadband avionics will be offered by Chelton Satcom (avionics and antennas), Esterline/CMC (antennas), EMS Technologies (avionics and antennas), Honeywell (avionics), Rockwell Collins (avionics), TECOM Industries (antennas), Thales (avionics) and Thrane & Thrane (avionics).

Each manufacturer has their own timetable for product availability.

Service provision

Aircraft operators must contract with an Inmarsat service provider. The service provider invoices for the service, either on a data volume or time basis, depending on the service used. Visit our website for contact details.

inmarsat.com/swiftbroadband

Figure 49: Second page of the SwiftBroadband brochure [41]; notice the poor coverage for Canada's High Arctic.

BGAN Usage Pricing

Usage costs on BGAN can be much higher than our VSAT satellite dish systems, but the advantage is extreme portability, broadband Internet, phone and fax with universal global coverage.

BGAN Prepaid Service Plans (global usage)	Prepaid Cost (U.S. Dolllars)
☐ BGAN 50 MB Prepaid Sim Card ($6.25 per MB)	$312.50*
☐ BGAN 100 MB Prepaid Sim Card ($6.25 per MB)	$625
☐ BGAN 150 MB Prepaid Sim Card ($6.25 per MB)	$937.50
☐ BGAN 255 MB Prepaid Sim Card ($6.11 per MB)	$1,560
☐ BGAN 1200 MB Prepaid Sim Card ($4.59 per MB + 360 free phone minutes)	$5,508
☐ BGAN Custom MB Prepaid Sim Cards (Lower cost per MB)	Call

- Prepaid plans (over 100MB) must be used within 12 months from activation.
- Phone calls are $0.99 cents per minute to any landline or cell phone worldwide. Free incoming calls.
- SMS texting is $0.50 per message for outgoing messages only. Free incoming.
- Streaming IP Services (CIR 1:1) are available with all plans over 100MB on request.
- *The BGAN 50 & 100 MB plans must be used within a 3 month period.
- There are no contracts with Prepaid plans. There are no additional charges with Prepaid plans.
- **Additional Plan Details** (Streaming - SMS - FAX - Static IP - Regular & Irregular phone rates)

BGAN Monthly Plans (global usage)	Monthly Cost (U.S. Dollars)
☐ Usage Only Internet Access ($7.50 per MB)	$57 + usage
☐ 100 MB of use per month ($4.95 per MB + 30 free phone minutes /mo)	$495 per month
☐ 750 MB of use per month ($3.73 per MB + 200 free phone minutes /mo)	$2,800 per month
☐ 2100 MB of use per month ($2.75 per MB + 300 free phone minutes /mo)	$5,800 per month

- Phone calls are $0.99 cents per minute to any landline or cell phone worldwide. Free incoming calls.
- SMS texting is $0.50 per message for outgoing messages only. Free incoming.
- All monthly plans are for a 12 month term and will renew unless requested otherwise.
- Streaming IP Services (CIR 1:1) are available with all plans over 100MB on request.
- There is an activation charge of $45 on the "usage only" and 100 MB plans.
- Accounts may auto-suspend if usage goes over plan levels (depending of preference).
- **Additional Plan Details** (Streaming - SMS - FAX - Static IP - Regular & Irregular phone rates)

Figure 50: Typical prices for BGAN communications from [42] .

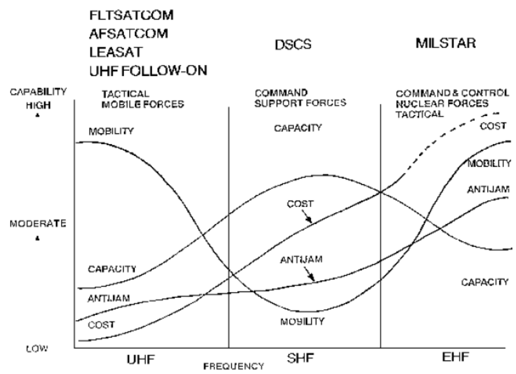
This page intentionally left blank.

Annex F SATCOM Overview from http://www.fas.org

SATELLITE COMMUNICATIONS (SATCOM) Page 1 of 12

7-17 Comparison of MILSATCOM Systems

Introduction a. The chart below gives an overview of the characteristics of the principal UHF, SHF and EHF military satellite communications systems. The chart shows relative capabilities in terms of mobility, anti-jam, capacity and cost.



FLTSATCOM, AFSATCOM, b. FLTSATCOM, AFSATCOM, LEASAT and UHF FollowOn support tactical mobile forces. Strategic users will be shifted to Milstar. UHF has the advantage of low cost user terminals that can operate well with small, portable

http://www.fas.org/spp/military/docops/army/ref_text/chap07b.htm 08/01/2010

SATELLITE COMMUNICATIONS (SATCOM) Page 2 of 12

LEASAT and UHF Follow-On antennas. The capacity is relatively low, however it is adequate to support single channel voice circuits. UHF has a relatively low capability to resist jamming of the satellites.

DSCS c. DSCS supports command and control and high volume data transmissions. The capacity of SHF systems is quite high. The cost of the terminals and the satellites is higher than that for UHF but many of the systems have already been acquired, therefore future costs should be moderate. SHF systems resist jamming better than UHF systems. Mobility is decreased with DSCS because of the size of the user terminals and antennas, and the power needed to operate them. Army terminals are deployable but require more than one truck per terminal.

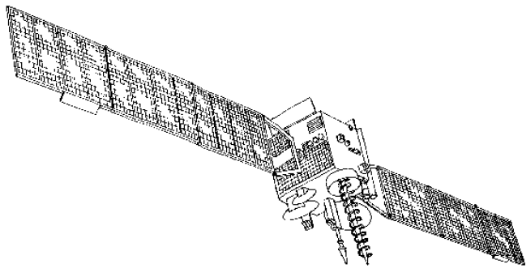
Milstar d. Milstar will support strategic level command and control and nuclear forces and provide added communications capability to tactical users. Cost of the satellites is high. A new family of user terminals is needed which will increase the overall cost of the system. Mobility will be enhanced because of the relatively small user terminals. The overall survivability of Milstar and its ability to effectively communicate even when jammed are much better than any of the other MILSATCOM systems. The designed capacity of the Block I satellites is relatively low. Changes in the Block II satellites will add more capacity. In addition, technological advances should increase the capabilities of EHF SATCOM systems.

7-18 International Military Satellite Communications Systems

Introduction a. In addition to US MILSATCOM satellites, the US military can use certain other MILSATCOM systems. Of course, permission must be obtained in advance.

SKYNET b. Skynet is a British military communications satellite system that was developed with US assistance. The first Skynet satellite was launched in 1969. Others were launched into geostationary orbit to complete the constellation. Their primary purpose is to provide military and government communication for Great Britain. Skynet IV has four XBand channels with bandwidths from 60 to 135 MHz which are compatible with Army SHF DSCS terminals, two UHF FLTSATCOM compatible channels and one experimental 44 GHz EHF channel.

http://www.fas.org/spp/military/docops/army/ref_text/chap07b.htm 08/01/2010



AN/FSQ-174 c. An AN/FSQ 174 control terminal will be installed at RAF Oakhanger, Great Britain for control of TACSAT terminals accessing the British SKYNET IV satellite.

NATO d. The NATO communication satellite program began in 1967 with the experimental use of two ground terminals communicating with a US satellite. The first NATO satellite was launched in 1970. NATO III is a spin stabilized satellite with a cylindrical body and a despun antenna platform on one end. NATO III has three communication channels in the SHF XBand (compatible with DSCS terminals). The NATO IVA satellite, launched in January 1991, is based on the Skynet IV design.

NATO Channels e. All channels are received through an earth coverage horn antenna which covers from the east coast of North America, across the Atlantic, all of Western Europe and the Mediterranean. Data is transmitted through either a wide coverage horn or a narrow beam antenna oriented only toward Western Europe. NATO also maintains an on orbit spare satellite to insure that communications can be provided continuously. There are about two dozen NATO ground terminals, most with 42foot antennas.

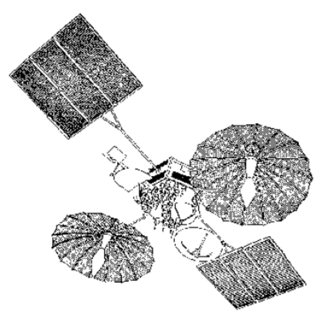
AN/FSQ-173 f. AN/FSQ173 control terminals were installed at Kester, Belgium and Folly Lake, Nova Scotia (Canada) for control of TACSAT terminals accessing NATO satellite.

7-19 Other Communications Satellites

Introduction a. In addition to the military communications satellites, there are others which are used by the Department of Defense.

Satellite Business System (SBS) b. The first Satellite Business Systems (SBS) satellite was launched in 1980. The commercial SBS provides integrated voice and data through dedicated digital communications networks. The satellites can also handle television broadcasts. The signals can only be received in the United States. DoD uses this system for high volume data transfer. The ground terminals are fixed stations. The military does not have tactical terminals that operate with this system.

TDRSS c. The Tracking and Data Relay Satellite System (TDRSS) is a key system in providing near continuous communications with the Shuttle without the reliance on the few ground stations. It is also used to relay data from low earth orbiting satellites such as LANDSAT. It is specifically designed to handle extremely high data rates of about 300 Megabits per second from a single source. TDRSS was the first system capable of operating simultaneously in three frequency bands: Two Sband transponders, twelve Cband transponders and two Kuband transponders. It is capable of communicating with up to 26 different satellites simultaneously. There are currently four TDRSS satellites in orbit.



7-20 Commercial International Satellite - Communications Systems

Introduction a. Satellite systems are ideally suited for international communications. This is particularly true for third world nations which do not have a well developed communications infrastructure. Satellite communications provide a cost effective way to connect into the world communications system.

Intelsat b. Intelsat is the acronym for the International Telecommunication Satellites and is also the name for the international consortium formed in 1964 which is made up of communications agencies from each of the participating countries. There are more than 120 member nations providing service to more than 150 countries. In most foreign countries, the national government operates the telephone and telegraph services. The U.S. government formed COMSAT Corporation to operate the ground terminals in the U.S. and to represent U.S. interests.

Intelsat Early Bird c. The first Intelsat satellite, called Early Bird, was launched in 1965. Since then many Intelsat satellites have been launched into geostationary orbit to provide continuous, worldwide communications service. By 1992 there were about 1,000 ground stations transmitting and receiving through 19 Intelsat satellites. More than 65% of all international telephone trunk traffic and most of the international television traffic is carried over Intelsat. The system is designed to provide communications between fixed stations and does not support mobile users.

Intelsate VI d. Intelsat VI satellites are the latest type to be launched. Each Intelsat VI satellite has a capacity of 24,000 voice circuits and three television channels.

Intelsat service e. Intelsat provides the following categories of service:

- International Telephony Service (which includes international telephone, data, telex and facsimile services).
- International Television Services. Intelsat carries almost all intercontinental television service.
- Intelsat Business Service (IBS).
- Intelnet, a digital service designed for data collection and distribution using small, inexpensive micro-terminals and large central hub Earth stations.
- VISTA Service, for domestic and international telecommunications services to rural and remote communities.
- Domestic telecommunications services, which offers the purchase or longterm lease of Intelsat transponders to satisfy domestic communications requirements.

Intelsat Bands f. Intelsat satellites use the 6/4 GHz band (Cband) and 14/12 GHz band (Kuband). (A 6/4 GHz band means a 6 GHz uplink frequency and a 4 GHz frequency downlink.)

Intelsat Ground Stations g. Intelsat ground stations are owned and operated by telecommunications organizations designated by their respective government.

DISA Use of Intelsat h. The Defense Information Systems Agency (IDISA) uses Intelsat to supplement its capabilities. Some Remote Tracking Stations of the Air Force Satellite Control Network (AFSCN) relay their data to the control centers over leased Intelsat circuits. During operation DESERT STORM, Intelsat provided approximately 25% of the communications capability external to the theater of operations. In addition, Intelsat provided direct telephone service between Saudi Arabia and the United States which allowed troops in the theater to call home.

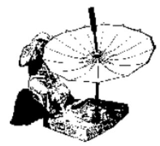
7-20 Commercial International Satellite - Communications Systems, cont'd

INMARSAT i. In 1970 the Intergovernmental Maritime Consultative Organization (IMCO), an international organization, issued a statement of requirements for a satellite communications system. In 1975, IMCO formed the International Maritime Satellite Organization (INMARSAT), a notforprofit consortium with representatives from 63 countries. Separate companies were formed in each of the participating countries. In 1982, INMARSAT took over the use of three MARISAT satellites and began service. Later, three MAREC satellites were added. Some newer INTELSAT satellites have INMARSAT transponder subsystems on them. A program called GAPFILLER involved the leasing of some channels on selected INMARSAT satellites in support of the U.S. Navy. There are nine Lband transponders on various satellites in geosynchronous orbit. These transponders provide two voice channels, one telegraph channel and one multichannel voice or 56 kbps data channel. INMARSAT terminals are common on most large commercial ships. The number of ground terminals is also expanding. The U.S. military used INMARSAT during Operations JUST CAUSE, DESERT STORM and RESTORE HOPE. Connectivity is provided through commercial phone systems to fixed sites or through portable INMARSAT terminals.

INMARSAT Terminals j. There are different INMARSAT terminals available from commercial manufacturers around the world. The type terminal used is dependent on the type of service desired and how it will be used.

INMARSAT-A

INMARSATA Ship Earth Stations (SES) have been in use since 1982. Many commercial and military ships have these INMARSAT terminals. Through these it is possible to contact a ship anywhere in the world. There are now some transportable INMARSATA terminals that can be moved in two suitcase sized containers. Typically the antenna is 1 meter across or larger. The Army

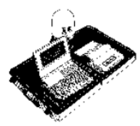


has approximately 120 INMARSATA terminals.

INMARSAT-B

The INMARSATB terminal is an improved, digital version, of the IMARSATA terminal. The size and weight are similar to an INMARSATA terminal. Both A and B type terminals require that the antenna be pointing at the satellite. For mobile service a tracking antenna must be used. The INMARSATB terminal can provide 9600 bps facsimile and good quality voice service at 16 kbps.

INMARSAT-C



An INMARSATC terminal can fit into one suitcase. The antenna is a hemispherical design which does not require accurate pointing and tracking. These small terminals provide text based services such as Email, telex and low rate data messages. As of February 1993, the Army had about 20 of these terminals.

INMARSAT-M

The INMARSATM terminal is the newest type. It is meant to provide a capability that is more than an INMARSATC terminal but less than an INMARSATB terminal. The M terminal provides a 4.8 kbps voice service and a facsimile rate of 2400 bps.

DESERT STORM Use of INMARSAT

k. During Operation DESERT STORM there were more than 150 small INMARSAT terminals in use by the US and coalition military forces, the CNN news team in Baghdad, Kuwaiti resistance fighters, and others. INMARSAT

terminals provide connectivity and compatibility between each of the U.S. military services, its allies and other agencies equipped with an INMARSAT terminal. INMARSAT terminals were also used successfully in Somalia.

7-21 Regional Satellite Communications Systems

Introduction

a. In addition to the many satellite communications systems providing worldwide communications links, there are also satellite systems providing regional coverage to various parts of the world.

US Domestic Communications Satellites

b. There are currently more than 25 satellites providing telecommunications service over North America. More than 50% of their capacity is used for video. About 18% of the capacity is used for telephone trunking, 15% for private data lines, 6% for government use and 4% is dedicated to private network users. The most common way to access these systems is over standard telephone lines to the operators' ground terminal. The Department of Defense uses some of these systems to support telephone and data communications within CONUS. Very Small Aperture Terminal (VSAT) technology is rapidly expanding the use of domestic COMSATS. These 3foot wide antennas are providing more capability of communication through the satellite directly to the intended addressee without reliance on other ground stations.

Foreign Communications Satellites

c. In addition to being members of Intelsat and/or INMARSAT, Russia, Japan, Germany, France, Great Britain, Australia, Italy, Spain, Mexico, Canada, China, Brazil, India, Indonesia and Thailand launched, purchased or leased satellites to meet their communication requirements. This gives these countries more control over the satellite and the traffic it carries.

7-22 Comparison of Military and Commercial SATCOM

Coverage and Orbits

a. MILSATCOM has worldwide coverage because the satellites used are in a variety of orbits including geostationary, low Earth, polar and Molniya. Commercial SATCOM systems prefer using geostationary satellites because the satellites provide continuous coverage, the antennas do not need to track the satellite. Spot beam antennas on the satellites provide high gain but this narrows the coverage to specific geographical areas. In addition, virtually all governments have some form of control over the use of commercial telecommunications systems within their country. These factors have encouraged the development of regional coverage systems.

Terminals and Service

b. In general, MILSATCOM users operate in a more demanding environment than civilian users, therefore MILSATCOM terminals must be more rugged. In addition, military users have a requirement to continue to operate under jamming conditions. The military requires a large number of compact, mobile terminals to support its mobile users who must independently communicate with the satellite. Civilian users with high data rate requirements generally gain access to the satellites through a central gateway facility which can have larger, fixed antennas. New technologies promise to increase the military's use of civilian SATCOM systems. Very small aperture antennas (VSAT) are enhancing civilian capabilities. VSATs are making civilian SATCOM systems more accessible and attractive to military users. Cellular telephone service is also an expanding field. Today, these systems are reliant on terrestrial central antennas. Service has been limited to metropolitan areas where there are enough subscribers to make the system profitable. There are proposals for a system of multiple satellites that would provide worldwide service similar to cellular telephones. The size of the civilian market for such mobile service is large and therefore it is expected that civilian requirements will drive the market. The military may be able to acquire nondevelopmental items (NDI) built to "best commercial practice" standards that would greatly enhance military communications.

Security c. Encryption of data, reduced probability of intercept and other security measures are mandatory for MILSATCOM systems. The military must use point of origin encryption when using commercial systems to handle sensitive data. For example, the STU III telephones used by the government provide good security when communicating over commercial phone systems that use satellites. MILSATCOM use of very narrow transmission beams, especially at EHF can provide a very low probability of intercept thus making the detection of ground transmitters more difficult.

Jamming d. The ability to continue to counter or compensate for jamming is highly desirable for military systems. At present this is not cost effective for commercial system operators. As technology advances it can be anticipated that commercial systems will implement some antijam capability to lessen susceptibility to inadvertent jamming caused by other systems. DSCS III provides some antijam capability and Milstar will provide considerably more.

Survive and Attack e. The ability to survive an attack on the satellites is desirable for MILSATCOM systems. Satellites can be degraded or disabled through a physical attack or by electromagnetic means such as nuclear burst, lasers, particle beams or other means. DoD has built some systems with hardened components and chosen certain orbital parameters to reduce the susceptibility of satellites to physical damage. Commercial systems do not have such protection. Of course, space is a hostile environment, therefore all satellites have some hardening of components to survive and be able to provide reliable communications.

7-23 MILSATCOM Request Procedures

JSC MOP a. All US military space assets are considered DoD/JCS assets, regardless of who developed the system or who operates it. As with any other critical resource with finite capabilities, procedures are necessary to insure that resources are allocated to those with the highest priorities and that the systems are not overloaded. In this way, space systems are available to the warfighting CINCs and subordinate commands from the military services. JCS Memorandum of Policy (MOP) Number 178, "Military Satellite Communications Systems" is the guiding document for MILSATCOM procedures. To manage requirements and resources, JCS established the MILSATCOM User Requirements Data Base (URDB) which evolved into the Integrated SATCOM Data Base (ISDB). It identifies requirements for MILSATCOM support based on JCS approved missions, provides operationally responsive MILSATCOM management and control for capacity allocation and adjudication, and ensures the effective and efficient use of MILSATCOM resources, based on operational priorities of mission requirements. The Defense Information Systems Agency maintains the ISDB for the JCS.

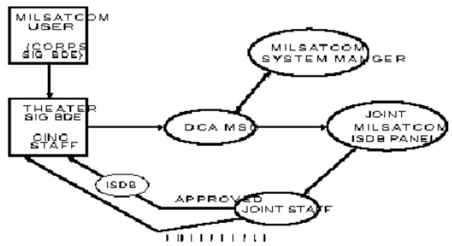
7-24 MILSATCOM System Managers

System Managers a. The MILSATCOM system managers include: Defense Information Systems Agency DSCS U.S. Navy FLTSAT/LEASAT/UHF FollowOn U.S. Air Force AFSATCOM Milstar

ISDB b. The MILSATCOM System Managers use the ISDB for the daytoday management of their systems. They review requests for access to the MILSATCOM systems against the ISDB to ensure the requirements have been validated in accordance with JCS MOP 178 procedures. Requirements not validated are referred to the J6, JCS before access to the satellite can be granted. JCS is updating MOP 178 and will publish it as Chairman's Memorandum Policy 37.

MOP 178 Request Procedures c. The diagram below depicts MOP 178 request procedures to obtain MILSATCOM service. Normally, the command that establishes the Net Control Station or hub submits the request for service but any command may submit a request. For example, an Army corps typically establishes a MILSATCOM net using AN/TSC85A and AN/TSC93A terminals. The corps signal brigade prepares the request for service and submits it to the theater CINC. If the theater CINC concurs, the request is coordinated with the supporting Regional Space Support Center (RSSC). If other CINCs or federal agencies are listed in the connectivity diagram, then the request must be coordinated before the request is forwarded. For example, if a CINC wanted to establish a link to an embassy, then the request must be coordinated with the Department of State. Requests for MILSATCOM service that do not support CINC assigned operational missions are submitted through that service's channels with an information copy to the CINC of that area. Urgent requests may be submitted directly to the JCS (J6Z) with information copies to the Defense Information Systems Agency MILSATCOM Systems Office (DISA MSO) and the appropriate MILSATCOM System Manager. Routine requests are forwarded to the DISA MSO. The DISA MSO forwards a copy to the appropriate MILSATCOM System Manager who will complete a technical and operational assessment within six weeks. (MILSATCOM users with short term, one time, nonrecurring requirements may be authorized access if the system manager determines that the requirement satisfies JCS MOP 178 criteria and if the request can be supported without adversely affecting other validated users.) For long term requests, the DISA MSO will develop a package for presentation of the request to the monthly meeting of the Joint MILSATCOM ISDB Panel. The panel is made up of representatives of each service and the JCS. They vote on whether the request is valid or not. The JCS makes the final decision to approve or disapprove the request. The JCS can approve urgent requests without validation if they support crisis, contingency, or wartime operational missions. If the request represents a validated requirement it is assigned a control number and added to the MILSATCOM ISDB.

DoD MILSATCOM REQUEST PROCEDURE



7-25 Technology Applications in the 1990's

Introduction a. The capabilities and types of communications satellites continue to grow. New military domestic and international systems with enhanced or new capabilities will be introduced.

Direct Broadcast b. One of the largest new applications will be direct broadcast satellites with emphasis on television. Of course, cable companies and individual users have been able to receive television broadcasts for quite some time. The cost of the ground receivers and antennas is, however, quite high. New high power direct broadcast systems will only need small antennas and the converters are less expensive. Germany and Great Britain already have direct broadcast television satellites. Newer systems are expected to use a small, flat surface antenna, about 2 ft x 2 ft, that could be placed in a window or on a roof.

Mobile Communications c. The use of satellites to provide mobile communications to ships around the world is already well established. Mobile cellular telephones have expanded rapidly in recent years. The cellular technology is limited to in or near metropolitan areas where there are enough subscribers to make the investment profitable. A satellite based system could provide mobile telephone service to all areas, in fact worldwide. With such a service you could call from any place or receive phone calls anywhere without the originator even knowing where you are.

Signal Processors d. Improved signal processors on satellites will increase capacity in all frequency bands. Improved bandwidth compression techniques and multiple access methods will also result in increased capacity. Improved chip technologies will lead to smaller transceivers that require less power.

Antennas e. Improved antennas will provide more precise spot beams which lowers the power required and limits interference from other areas.

Inter-satellite Links f. Intersatellite links will provide direct connectivity between two or more satellites, thus eliminating the need for intermediate ground stations when sending traffic over long distances.

LIGHTSAT g. Lightweight, relatively inexpensive satellites are being developed to fill unique requirements or to fill gaps in existing systems. The Army has a significant number of UHF SATCOM transceivers but the satellites are heavily used by high priority traffic. The Army is very interested in the capabilities of lightsats which could be launched on demand to support specific operations.

[RETURN]

Annex G Small Unmanned Aerial Vehicles (UAVs)

UAVs also referred to as Unmanned Aerial Systems (UAS), Remotely Piloted Vehicles (PVRs), and Unmanned Vehicle Systems (UVS) come in a spectrum of sizes, from the largest such as the Global Hawk (HALE) and Predator (MALE) down to the smallest minis, micros and nano sized. Of particular interest to this report is the so-called “mini” sized UAVs such as the Aerosonde (Mk IV), the Boeing/Insitu ScanEagle, and its most recent variant the Integrator. These are just a few representative types, and their inclusion in this report is not intended to endorse any of them, but to show what some of the current capabilities are and how they might be used for arctic surveillance.

G.1 Aerosonde System (Mk III & IV)

The Aerosonde UAV is developed and operated globally by Aerosonde Pty Ltd (AePL) and Aerosonde North America (AeNA). It has been undertaking operations for more than 7 years, was the first UAV to cross the Atlantic Ocean, has flown for over 32 h in one stretch and has undertaken continuous operations with relay aircraft extending over several days. The great flexibility of the Aerosonde, combined with a sophisticated command and control system, enables deployment and command from virtually any location. The following information on the Aerosonde was mostly obtained from documentation on the Aerosonde website [43] and screen captures from some of their promotional videos.[44]

The Aerosonde UAV [43]

The Aerosonde was designed to a specification that would allow long endurance and economical flights anywhere in the World. The specifications are provided in Table 9.

Table 9: Specifications of Mark 3 Aerosonde UAV

Specifications	
Weight, wing span	27-30 lb, 10 ft
Engine	24 cc, 1.2 kW, fuel injected using premium unleaded petrol
Navigation	GPS
Operation	
Staff for Launch and Recovery	3 people: Controller, Technician, Pilot/Maintenance
Staff for Flight Operations	1 Person for up to 3 aircraft
Ground Equipment	Proprietary Staging Box, personal computer (laptop), GPS antenna, aviation and local communications radios
Flight	Fully autonomous, under Base Command
Launch and Recovery	Launch from car roof rack (catapult option), land on belly, Autonomous or with pilot
Ground & air communications	UHF or Satcoms (Iridium) to Aerosonde, VHF to field staff and other aircraft, internet to command center and users.
Performance	
Speed, Climb	18 – >32 ms^{-1}, Climb >2.5 ms^{-1} at sea level
Range, Endurance with no additional payload	>1800 miles, >30 h
Altitude Range	Up to 20,000 ft (medium weight)

Payload	Maximum 5 lb with full fuel load
Standard Instrumentation	
Temperature, Pressure, Humidity, Wind	2 Vaisala RSS901 Sondes for temperature, pressure and humidity, and a proprietary wind system.

Aerosonde Payloads

In addition to the standard meteorological instruments in Table 9, a range of other payloads has been flown on the Aerosonde and further additions are anticipated. These are described in Table 10.

Table 10: Aerosonde Payloads.

Payload Type	Mission	Status
Surface Temperature: KT11 IR Sensor	Meteorological and environmental	Operational
Still Camera: Olympus	Surveillance, environmental, biological.	Operational
Video Camera: Various	Surveillance, environmental, biological.	Operational in fixed mounted mode
Electronic Warfare	Surveillance and deterrence	Under development, with initial test flights accomplished
COMINT: Various instruments	Surveillance and deterrence	Under development
Chemical Sensor: Sulfur and carbon compounds, NASA JPL	Volcanic plume and atmospheric chemistry	Flight tests completed
Radio data relay	Support field operations	Under development
Magnetometer: Purpose built for Aerosonde	Mineral survey	Instrument nearing completion
SAR	Surveillance	Suitable unit identified and funded for integration
Cloud Physics: NCAR Heymsfield	Meteorological and environmental	Unit being flight tested
Laser Altimetry	Surveillance, ice and topographical	Under consideration

Extra capability will be required for the envisaged missions under the AMRF, especially in regard to surveillance and reconnaissance payloads. Whilst the details will require feedback from potential users, a generic estimate is included under development requirements.

The Aerosonde Deployment and Command System

Aerosonde UAVs are fully autonomous and capable of making sophisticated operational decisions. They are operated in full accordance with civil aviation regulations. Through the Aerosonde Global Reconnaissance Facility (AGRF), Aerosondes are deployed from designated launch and recovery sites, operate from a specified command center (with communications through the Iridium satellite system) and provide data to users through the Aerosonde Virtual Field Environment (AVFE).

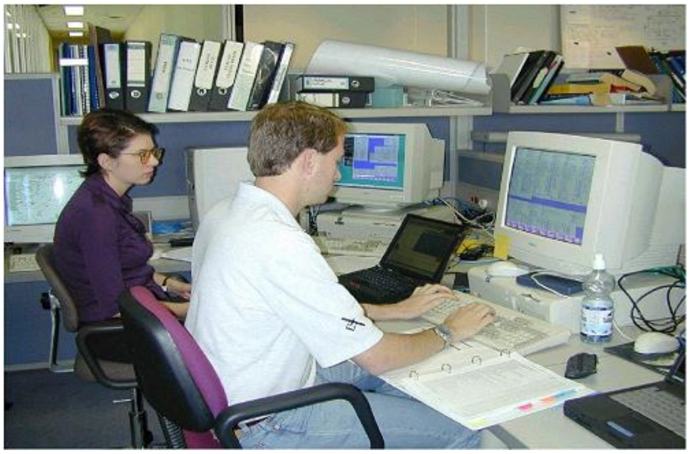


Figure 51: The command center is based on PC technology and easily located in an office environment.

The Command Center is the focus of the entire operation, providing for mission coordination, a monitoring, regulatory and safety watch, the tasking of multiple mission requirements, and monitoring the flow of data. A global command center has been operational in Melbourne, Australia, for several years, and another command center is under consideration for Hawaii. For the US operations, a permanent command center would be located on the AMRF Base and a mobile command center would be moved to support operational requests. For example, the mobile command center could be located at a field program headquarters, or with the staff in control of an emergency situation.

Figure 52: A minimalist Launch and Recovery Site

Launch and Recovery Sites are established on an as needs basis. The requirements are relatively simple, a large field or open area, a small shed or other protection from the elements and a vehicle from which the aircraft is launched. When on mobile operations the entire operation can be undertaken out of a vehicle or a tent, subject to weather conditions.

The Aerosonde Virtual Field Environment is a web-based data display system that enables users to access data and monitor the progress of missions in real time from their own personal computers or office workstations. Users can also develop modified missions and upload these to the command center for implementation.

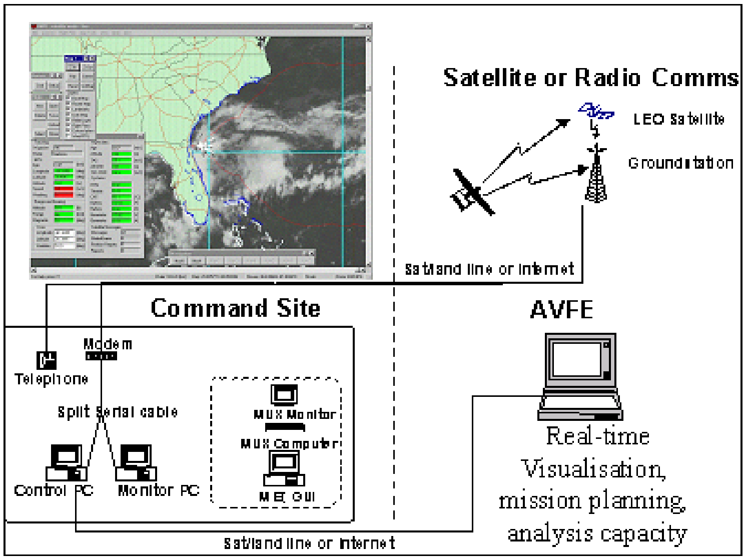


Figure 53: A typical set up and display for both the command center and virtual field environment, showing an Aerosonde in operation off the US east coast during the NASA CAMEX, overlain on satellite imagery.

Aerosonde Field Services includes all training, maintenance and specialized field operations. We have participated actively in the development of the Australian UAV regulatory environment (the first in the world) and all operators will be certified under these new regulations. We are also actively involved in the establishment of FAA guidelines for UAV operations.

Aerosonde Mk IV

Specifications	
Weight	27-30 lb, 33 lb with fuel + payload
Wing span	9.4 ft
Length	5.7 ft
Engine	Single cylinder fuel injected 1.74 hp using premium unleaded fuel
Navigation	GPS
Electrical	18vdc @30-75W (Mk 4.1)
Performance	
Speed	25 – >39 ms^{-1} (49-75 knots)
Operating Temperature	-30° to +110° F (-34° to 43°C)
Range, Endurance with no additional payload	>1800 Nm, >30 h
Altitude Range	Up to 20,000 ft (medium weight)
	Service ceiling 15000 ft
Payload + fuel capacity	12.1 lb

Figure 54: Aerosonde launch options: via a launch catapult (upper) or ground vehicle; recovery is by belly landing. [Photos are screen captures from an Aerosonde promotional video [44]]

Figure 55: Cold weather operation testing in Barrow, Alaska: over 1000 h of successful operation [Screen captures from an Aerosonde promotional video [44]].

G.2 ScanEagle

The following are figures are reproductions of the Boeing/Insitu ScanEagle brochure, as well as screen captures of internet reviews of the new NanoSAR a very small, 900g Synthetic Aperture Radar which can be used as one of the payloads on either the ScanEagle or the Integrator.

Figure 56: first page of the ScanEagle brochure [45]

ScanEagle®

UNMANNED AIRCRAFT SYSTEM | **PRODUCT SPECIFICATIONS**

PROVEN ScanEagle® unmanned aircraft system (UAS) is a low-cost solution with a small operational footprint that delivers high-quality imagery for intelligence, surveillance, and reconnaissance (ISR). ScanEagle, developed in partnership with Boeing, is currently in service with the U.S. Department of Defense, the Australian Defence Force, and other allied foreign militaries.

FLEXIBLE Challenging weather conditions, unprepared terrain, and shipboard operations are easy with Insitu's pneumatic catapult launcher and unique SkyHook® recovery system. Aircraft launch and recovery are performed safely and autonomously on land and at sea without a net or runway.

STRAIGHTFORWARD Because of its light weight and small system footprint, the ScanEagle UAS has low personnel requirements—only two operators are necessary. Insitu's aircraft control software is user-friendly, and advanced automatic object-tracking technology greatly reduces operator workload.

VISIONARY A standard ScanEagle unmanned aircraft (UA) carries a high-resolution electro-optic (EO) or infrared (IR) camera on a lightweight, inertially stabilized turret system. With communications range of over 55 nautical miles (100 km) and endurance of 24+ hours, the ScanEagle UAS is a versatile platform. Because the aircraft is completely modular, critical components can be swapped quickly in the field to ensure that ScanEagle is mission-ready.

Insitu systems have demonstrated safety and reliability in more than 200,000 hours of operation. A variety of sensor options are available for expanded capabilities—contact us to learn how ScanEagle can be customized to meet your needs.

Insitu, Inc.
118 East Columbia River Way
Bingen, WA 98605

509.493.6858
contactus@insitu.com

A ScanEagle system includes:

- One or More ScanEagle UA
- Pneumatic Launcher
- SkyHook Recovery System
- Ground Control Station

UPGRADES

- AIS for Maritime Domain Awareness
- Heavy Fuel Engine with 32 Hours Endurance
- Hush Engine for Reduced Acoustic Signature
- Mid-Wave IR Sensor for Increased Nighttime Resolution
- Mode C Transponder for Aircraft Deconfliction
- ROVER Support

DIMENSIONS		
Wing Span	10.2 ft	3.11 m
Length	4.5 ft	1.37 m

WEIGHTS		
Empty Structure Weight	28.8 lb	13.1 kg
Max Takeoff Weight	44.0 lb	20.0 kg

PERFORMANCE		
Max Horizontal Speed	80 knots	41 m/s
Cruise Speed	48 knots	25 m/s
Ceiling	19,500 ft	5,944 m
Endurance		24+ hours

SYSTEM FEATURES	
Propulsion	1.9 hp (1.4 kw), 2-stroke engine
Fuel	Gasoline (100 octane unleaded non-oxygenated gas) or Heavy fuel (JP5, JP8, Jet-A)
Navigation	GPS / Inertial / Magnetic
Launch	Pneumatic catapult
Recovery	SkyHook wingtip capture

PR102309

Figure 57: Second page of the ScanEagle brochure [45].

G.3 Boeing/Insitu Integrator

Figure 58: Fist page of the Integrator brochure [46].

Integrator™

UNMANNED AIRCRAFT SYSTEM | **PRODUCT SPECIFICATIONS**

REVOLUTIONARY Insitu's Integrator™ unmanned air vehicle (UAV) is the next-generation addition to Insitu's operationally mature family of unmanned aircraft systems (UAS). Designed to address our customers' most pressing needs, Integrator delivers exceptional situational awareness with superior high-quality imagery and long endurance at a fraction of the cost of larger UAS. But, what makes Integrator really stand out from the crowd is the ease with which it accepts payload integration for a wide variety of missions. Payload bays are plug-and-play, so your cargo becomes airborne as quickly and seamlessly as possible.

ADVANCED Integrator's baseline sensor package includes inertially stabilized electro-optic (EO), long-wave infrared (LWIR), and mid-wave infrared (MWIR) cameras, with IR marker and laser rangefinder on a single, long-endurance vehicle. For other types of missions, these sensors may be removed to increase the available payload weight or to extend endurance. Integrator has line-of-sight communications range of over 55 nautical miles (nm) with extended beyond-line-of-sight mission radius of up to 550 nm.

COMPLEMENTARY Integrator and ScanEagle® unmanned aircraft are interoperable, using common ground system equipment. A single launcher and SkyHook® recovery system can be used to launch and recover both aircraft, making them a natural team in any theater. Operation is completely autonomous from launch to recovery through a user-friendly drag-and-drop interface that keeps operator workload at a minimum. Launch and recovery are performed on land and at sea with no nets involved and no runway required.

Insitu systems have demonstrated safety and reliability in more than 200,000 hours of operation for both military and commercial purposes. Contact us to learn how Integrator can meet your unmanned system needs.

Insitu, Inc.
118 East Columbia River Way
Bingen, WA 98605

509.493.6858
contactus@insitu.com

An Integrator system includes:

- One or More Integrator Air Vehicles
- Pneumatic Launcher
- SkyHook Recovery System
- Ground Control Station

STANDARD SENSOR PACKAGE

- Electro-Optic (EO)
- Long-Wave Infrared (LWIR)
- Mid-Wave Infrared (MWIR)
- IR Marker
- Laser Rangefinder

DIMENSIONS

Wing Span	16 ft	4.8 m
Length	7.2 ft	2.2 m

WEIGHTS

Payload Bay Limits (combined)	50 lb	22.7 kg
• Payload Bay	35 lb	15.8 kg
• Nose Bay	25 lb	11.3 kg
• Hardpoint (each)	15 lb	6.8 kg
Max Takeoff Weight	135 lb	61.2 kg

PERFORMANCE

Max Horizontal Speed	90 knots	46.3 m/s
Cruise Speed	55 knots	28.3 m/s
Ceiling	20,000 ft	6,100 m
Endurance	24 hours	

SYSTEM FEATURES

Propulsion	8 HP, advanced reciprocating engine
Fuel	Gasoline or heavy fuel
Navigation	Differential GPS/Athena Guidestar
Launch	Pneumatic catapult
Recovery	SkyHook wingtip capture

ScanEagle is a registered trademark of The Boeing Company. SkyHook is a registered trademark of Insitu, Inc. Information contained herein is subject to change without notice. Some technologies may not be available in all areas. Copyright © Insitu, 2009. All rights reserved.
PR0709

Figure 59: Second page of the Integrator brochure [46].

G.4 NanoSAR Synthetic Aperture Radar from imSAR (www.imsar.com)

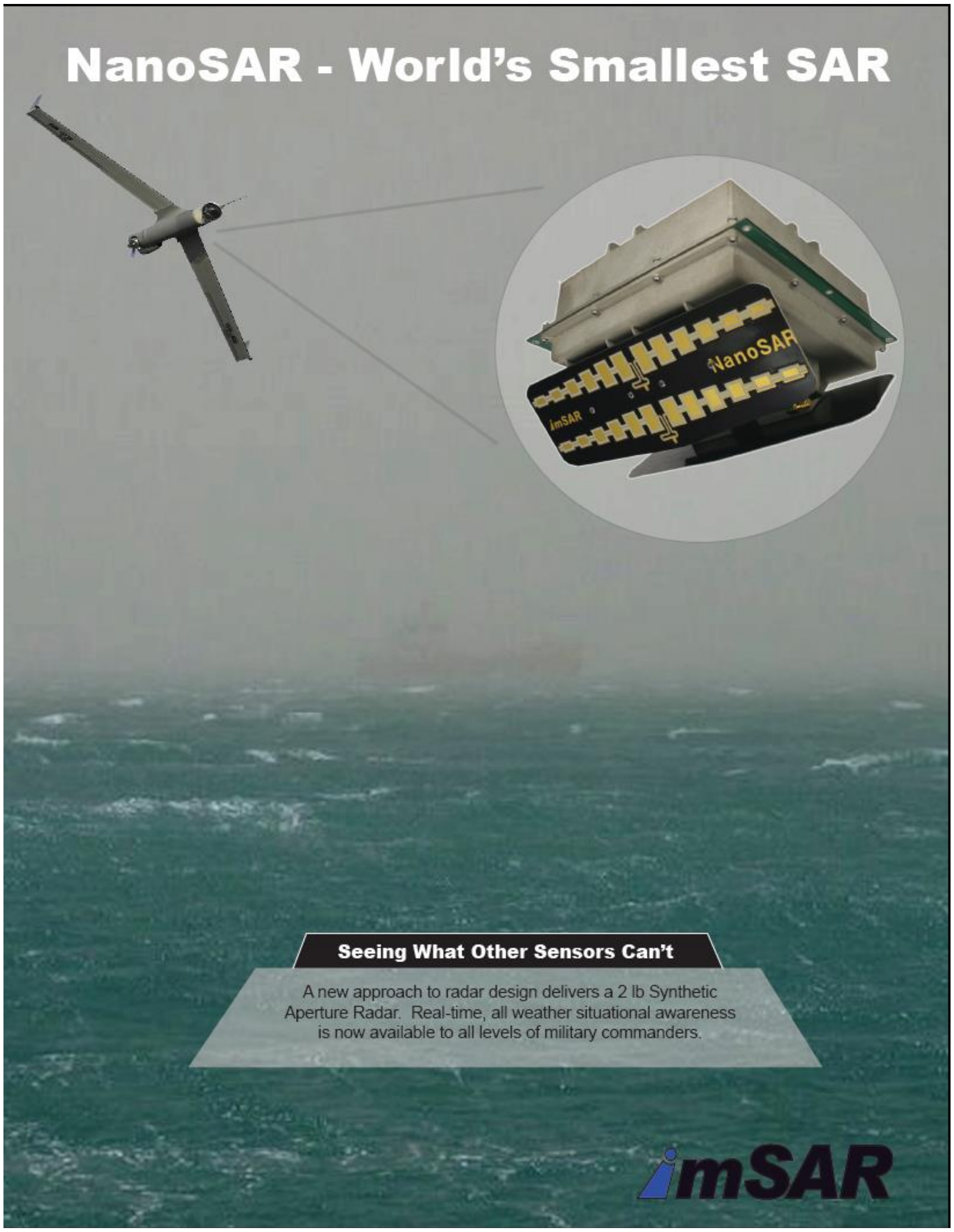


Figure 60: First page of the NanoSAR system fact-sheet from imSAR [47] .

Figure 61: Second page of the NanoSAR fact-sheet [47].

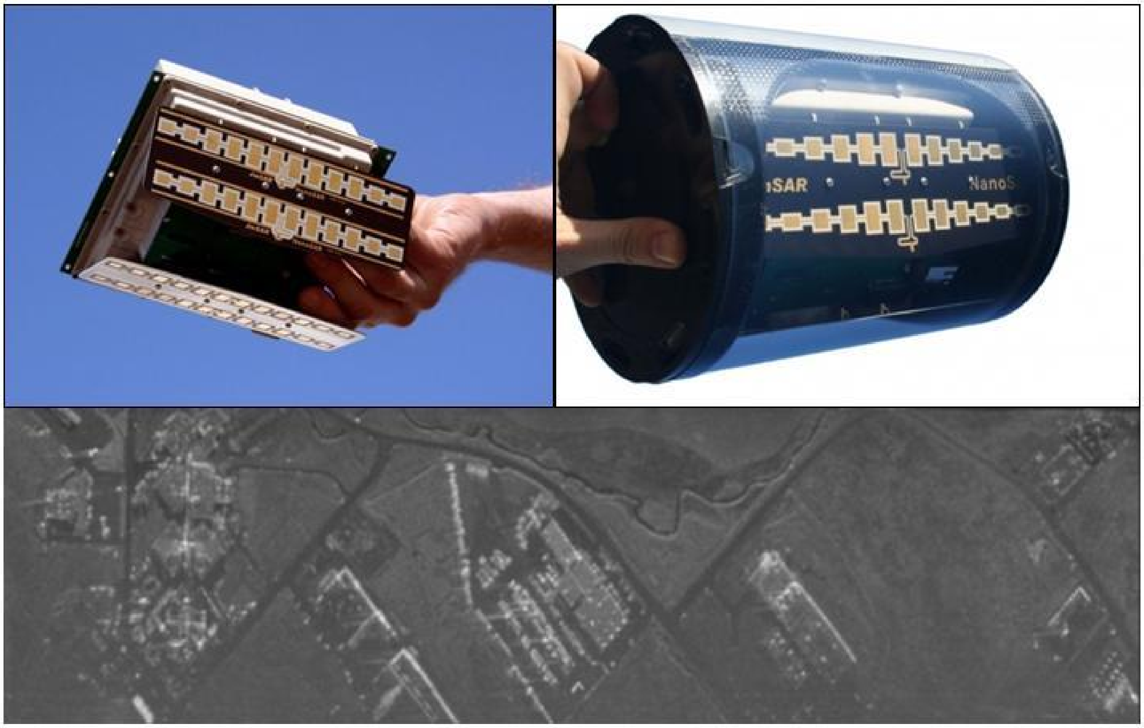


Figure 62: Pictures of the NanoSAR system and a SAR image it produced [48]

List of symbols/abbreviations/acronyms/initialisms

ADAM	Airborne Data Acquisition and Management (system)
AFB	Air Force Base
AIS	Automatic Information System
AOR	Area of Regard
ASIS	American Society for Industrial Security
ASL	Above sea level
ASP	Air Surveillance Program
CANMARNET	Canadian Maritime (surveillance) Network
CASR	Canadian American Strategic Review
CCD	Charge Coupled Device
CCG	Canadian Coast Guard
CIISD	Canadian and International Industrial Security Directorate
CIS	Canadian Ice Service (part of Environment Canada)
COMINT	Communications Intelligence
DEW	Defence Early Warning
DFO	(department of) Fisheries and Oceans Canada
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
DXR	Dispatch Reliability
EEZ	Exclusive Economic Zone
ELINT	Electronic Intelligence
EO	Electro-Optic
ESM	Electronic Support Measures
FH	Flight Hour
FLIR	Forward Looking Infra Red
FPS	Force Planning Scenario

GCCS-M	Global Command and Control System – Maritime
GFE	Government Furnished Equipment
GIS	Geographic Information System
GOC	Government of Canada
GPS	Global Positioning (Satellite) System
GSM	Global System for Mobile Communications; originally from Groupe Spécial Mobile
HALE	High Altitude Long Endurance
IR	Infra-red
ISR	Intelligence Surveillance and Reconnaissance
ISAR	Inverse Synthetic Aperture Radar
ISTOP	Integrated Satellite Tracking of Oil Polluters
JUSTAS	Joint Unmanned Surveillance and Target Acquisition System
KTAS	Knots air speed
LEO	Low Earth Orbit
MALE	Medium Altitude Long Endurance
MARLANT	Maritime Forces Atlantic
MDA	Maritime Domain Awareness
MDSS	Medium Data-rate SATCOM System
MNR	Ministry of Natural Resources
MSOC	Maritime Security Operations Center
MUN	Memorial University of Newfoundland
MXR	Mission Reliability
Nm or nmi	Nautical mile
NRCan	Natural Resources Canada
NWP	Northwest Passage
NASP	National Air Surveillance Program
NRT	Near Real Time
NWS	North Warning System
OTH	Over The Horizon
OGD	Other Government Department
OTP	On-Time Performance
PAL	Provincial Aerospace Limited

PPO	Pollution Prevention Officers
PWGSC	Public Works and Government Services Canada
RAVEN	Remote Aerial Vehicle for Environmental Monitoring
RCMP	Royal Canadian Mounted Police
R&D	Research & Development
RCC	Rescue Coordination Centre
RMP	Recognized Maritime Picture
RPV	Remotely Piloted Vehicle
RT	Real Time
SIS	Surveillance Information Server/Service
SAR	Synthetic Aperture Radar
SaR	Search and Rescue
SATCOM	Satellite Communications (system)
SLAR	Side Looking Airborne Radar
SR	Surveillance and Reconnaissance
TC	Transport Canada
TWT	Travelling Wave Tube
UAS	Unmanned Aerial System
UAV	Unmanned/Uninhabited Aerial Vehicle
UFO	UHF Follow On
UHF	Ultra High Frequency
USCG	United States Coast Guard
UV	Ultraviolet

This page intentionally left blank.

Glossary

(Canadian) Arctic Archipelago

This is the term referring to the group of islands lying north of the Canadian mainland and the Arctic Circle that consists of about 100 “major” islands and thousands of minor ones. Some of the larger, more commonly known major islands include (from roughly west to east) the following: Banks, Prince Patrick, Melville, Victoria, Prince of Wales, Bathurst, King William, Cornwallis, Somerset, Devon, Ellesmere, and Baffin Islands.

Cold-Soaking

This is an aviation term that usually refers to exposing an air-frame, for long periods of time, to extremely cold temperatures, either in flight, or on the ground. This can cause either mechanical or electronic systems to malfunction for a number of reasons. These include (but are not limited to) the following:

- Ice or frost build-up on airframe surfaces that increase the aircraft’s drag, jam mechanical structures such as rudders or ailerons, or obscure sensor apertures;
- Ice accumulations breaking off in flight then hitting and damaging airframe structures; or
- Subjecting sensor (or other electro-mechanical) systems to environments outside their acceptable temperature ratings.

Ice or frost build up can be the result of the “cold-soaked” aircraft causing water to condense and freeze on the surface of the wings and fuselage when flying through more humid air, or through rain. Cold-soaking of aircraft structures, such as wings, can also be caused by cooling from fuel tanks; this is more common with wing fuel tanks.

“The Canadian Arctic” or just “The Arctic”

This term refers to Canadian territories located north of Arctic Circle (66°N) and stretching to the geographic North Pole at 90°N.

The “High Arctic”

Within the context of this report, this refers to the areas located within the (Canadian) Arctic Archipelago, i.e. north of the Canadian mainland between roughly 68°N and the geographic North Pole.

High Altitude

For UAVs this refers to flying altitudes in excess of 9000 m (over 30000 ft)

Medium Altitude

For UAVs this refers to flying altitudes between 3000 m and 9000 m (10000 to 30000 ft)

Long Endurance

For UAVs this refers to platforms capable of sustaining missions of many hours duration, often exceeding 24 h. Based on flight trials (e.g. 26+ hour trans-Atlantic flight), the Aerosonde might fit into this category.

"The Canadian North" or just "The North"

In the broadest sense (as intended in this report), this refers to areas of Canada located north of latitude 60°N which includes the northern tips of Labrador and Quebec; however, it is often used as a colloquial term to collectively refer to Canada's northern territories, i.e. Nunavut, NWT, and Yukon.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence R&D Canada – Ottawa 3701 Carling Avenue Ottawa, Ontario K1A 0Z4	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED (NON-CONTROLLED GOODS) DMC: A REVIEW: GCEC JUNE 2010

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Arctic Surveillance Civilian Commercial Aerial Surveillance Options for the Arctic

4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used)

Brookes, D.; Scott, D.F.; Rudkin, P.

5. DATE OF PUBLICATION (Month and year of publication of document.) November 2013	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 152	6b. NO. OF REFS (Total cited in document.) 49

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Report

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

Defence R&D Canada – Ottawa
3701 Carling Avenue
Ottawa, Ontario K1A 0Z4

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.) 11HI01; 15ej01	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.) W7714-061027/001/TOR
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.) DRDC Ottawa TR 2013-142	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

Unlimited

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

The heightened interest in the Arctic has prompted the Canadian Government to investigate effective and affordable methods of monitoring this vast area, including private sector airborne surveillance. This study was accomplished with domain expertise from Provincial Aerospace Limited of St. John's, NL; it describes their current worldwide surveillance, reconnaissance and enforcement activities, and extrapolating them to Canada's North. Similar arctic services would require supplementing their current fleet with manned aircraft out of Goose Bay or Iqaluit and one at Inuvik, providing surveillance of up to 4000 h/year at approximately $5000/h with 8 h missions every 1.5 to 2 days. This would allow monitoring of the arctic approaches and internal waterways on a regular basis at roughly half the cost of an Aurora. Small Remotely Piloted Vehicles (RPV) for tactical surveillance and reconnaissance were also briefly studied. New miniaturized devices allow small RPVs with limited payload capacities to carry a mixture of electro-optic and infrared sensors, Automatic Identification System receivers, miniature (short range) Synthetic Aperture Radars, etc. These platforms offer much smaller requirements for fuel, maintenance and operating crews, at a lower cost. However, they must still prove their capabilities in the harsh Arctic environment.

L'intérêt **marqué pour l'Arctique a** incité le gouvernement du Canada à examiner des méthodes de surveillance efficaces et abordables, y compris les services de surveillance aérienne offerts dans le secteur privé, pour cet immense territoire. La présente étude réalisée avec l'expertise de la société Provincial Aerospace Limited, de St. John's (NL), décrit les activités mondiales actuelles de surveillance, de reconnaissance et de renforcement de l'entreprise, et les extrapole pour le nord du Canada. Pour des services semblables dans l'Arctique, il faudrait ajouter à sa flotte actuelle un aéronef piloté à Inuvik, de même qu'à Goose Bay ou Iqaluit, afin d'offrir jusqu'à 4 000 h de surveillance par an, au coût approximatif de 5 000 $ par heure, avec des missions de 8 h tous les 1,5 à 2 jours. Cela permettrait de surveiller régulièrement les approches dans l'Arctique et les voies navigables intérieures pour environ la moitié du coût d'exploitation d'un Aurora. Les petits véhicules téléguidés (VTG) pour la reconnaissance et la surveillance tactique ont également été examinés brièvement. De nouveaux appareils miniaturisés permettent aux petits VTG ayant une capacité de charge limitée de transporter des détecteurs électro optiques et infrarouges, des récepteurs du Système d'identification automatique, des radars à synthèse d'ouverture (courte portée) et autres. Ces plateformes nécessitent beaucoup moins de carburant, d'entretien et d'équipage à un moindre coût. Toutefois, il reste à démontrer leurs capacités dans les conditions difficiles de l'Arctique.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Provincial Aerospace Limited;PAL;Arctic;Maritime Domain Awareness;MDA, Recognized Maritime Picture;RMP;surveillance; reconnaissance;ISR;NASP;ISTOP;JUSTAS;unmanned aerial vehicle;UAV;UAS;remotely piloted vehicle;RPV;maritime patrol aircraft;MPA;King Air;Global Hawk;Aerosonde;Scaneagle;nanosar;SAR;CP-140;Aurora;Northwest Passage;NWP;radar;EO/IR;Measures of Performance;MOP;MARLANT;MARPAC